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**A PILOT TRAINING MANUAL FOR THE TERMINAL
CONFIGURED VEHICLE ELECTRONIC HORIZONTAL
SITUATION INDICATOR**

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SUMMARY

This manual presents the initial phase of a training course for the Terminal Configured Vehicle Electronic Horizontal Situation Indicator (EHSI). Reference 1 describes the total training program, its various components, and how they relate to each other. This manual provides the basic instructional format for the introduction to the EHSI and the strategy for learning the EHSI symbology and their interpretation. The strategy is to start with the basic symbols which are present at all times, to present the optional symbols, and then to add appropriate symbols as desired during the various portions of a flight. Each page of this manual is divided into two parts. The upper half of the page is a reproduction of the EHSI display or various other instructional material, such as title pages, quizzes, answer pages, etc. The bottom half of the page contains text associated with the upper half. This allows for easy production of an audio-visual package (see references 1 and 2) when required for use with large groups of students.

N81-20044[#]



Terminal Configured Vehicle Program

This is the second in a series of presentations (see ref. 2) on advanced display and control systems currently being evaluated in the Terminal Configured Vehicle (TCV) Program at the National Aeronautics and Space Administration's Langley Research Center.



The TCV Program is an advanced technology development activity designed to enable transport aircraft to operate with increased safety in reduced weather minima such as Category III. These operations would occur in future high-density terminal areas equipped with new technology landing systems, navigational aids and increased air traffic control automation.

Evaluation of:

1. New concepts in airborne systems:

- a. avionics
- b. air vehicle

2. Operational Flight Procedures

Within the scope of the TCV Program is the evaluation of new concepts in airborne systems, both avionics and the air vehicle, and operational flight procedures.

TCV Objectives

1. Reduce approach and landing accidents
2. Reduce weather minima requirements
3. Increase airport and airway capacity
4. Increase fuel efficiency
5. Reduce terminal area noise

More specifically, the TCV Program's objectives are to:

Reduce approach and landing accidents,
Reduce weather minima requirements,
Increase airport and airway capacity,
Increase fuel efficiency, and
Reduce terminal area noise.

1. Flight Control Systems
2. Flight Display Systems

Two of the concepts in the TCV Program deal with advanced flight control systems and electronic flight display systems.

Electronic Horizontal Situation Indicator

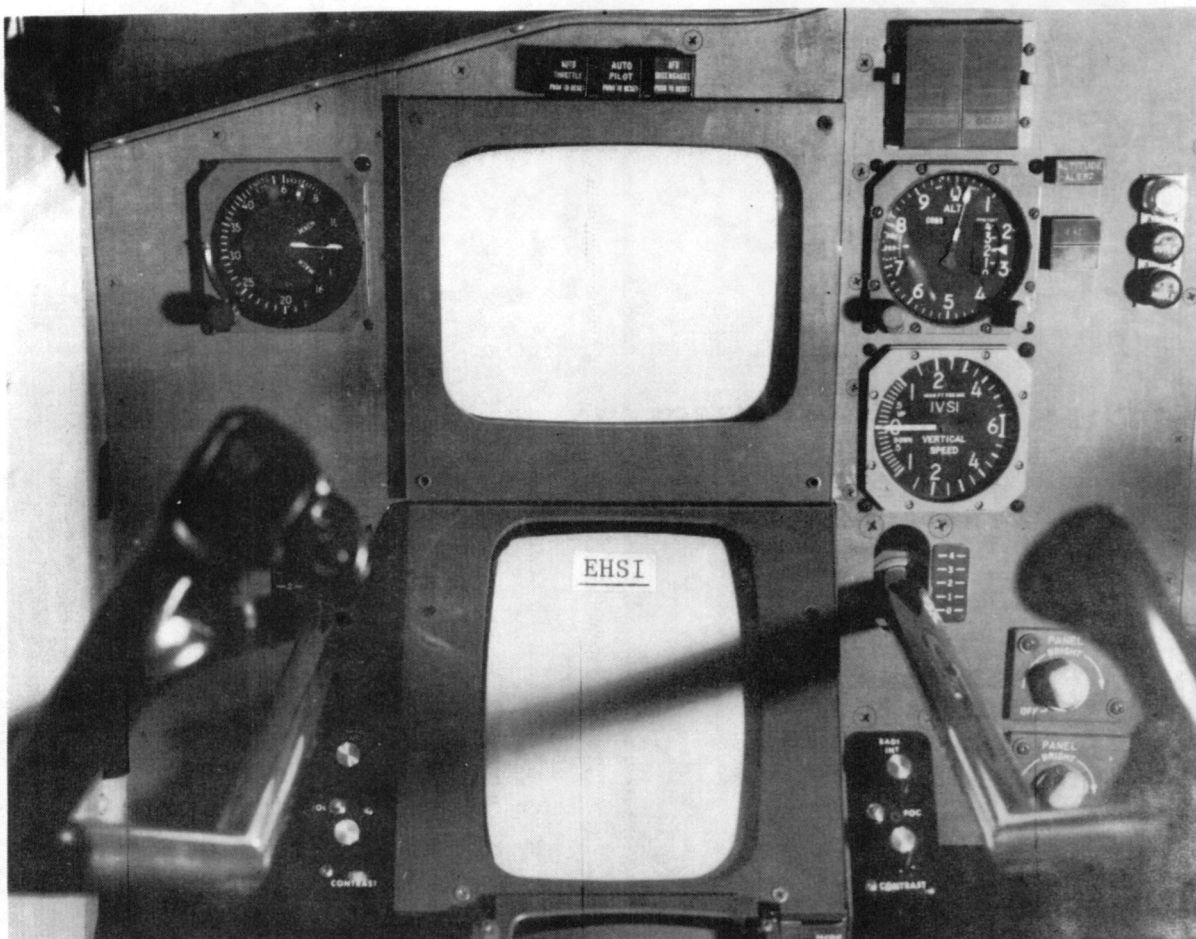
This presentation will introduce you to one of the electronic displays - The Electronic Horizontal Situation Indicator - referred to as the EHSI.

Identify and Interpret the EHSI'S Symbols

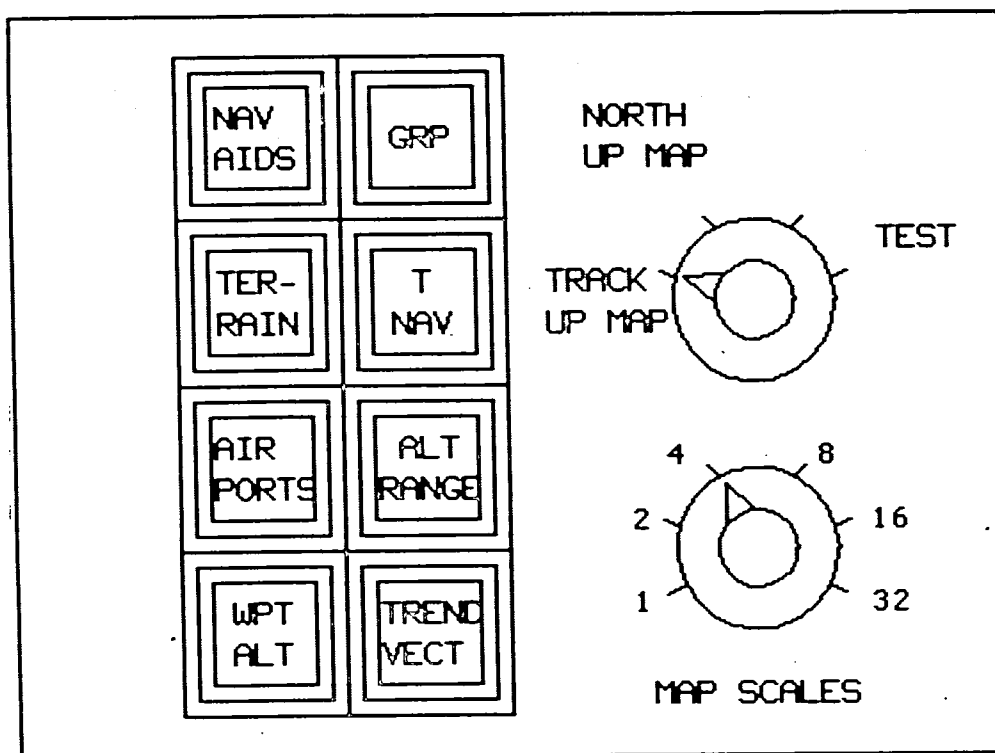
Upon completion of this presentation, you should be able to correctly identify and interpret each symbol on the EHSI,

Relate EHSI display response to
aircraft navigation and control

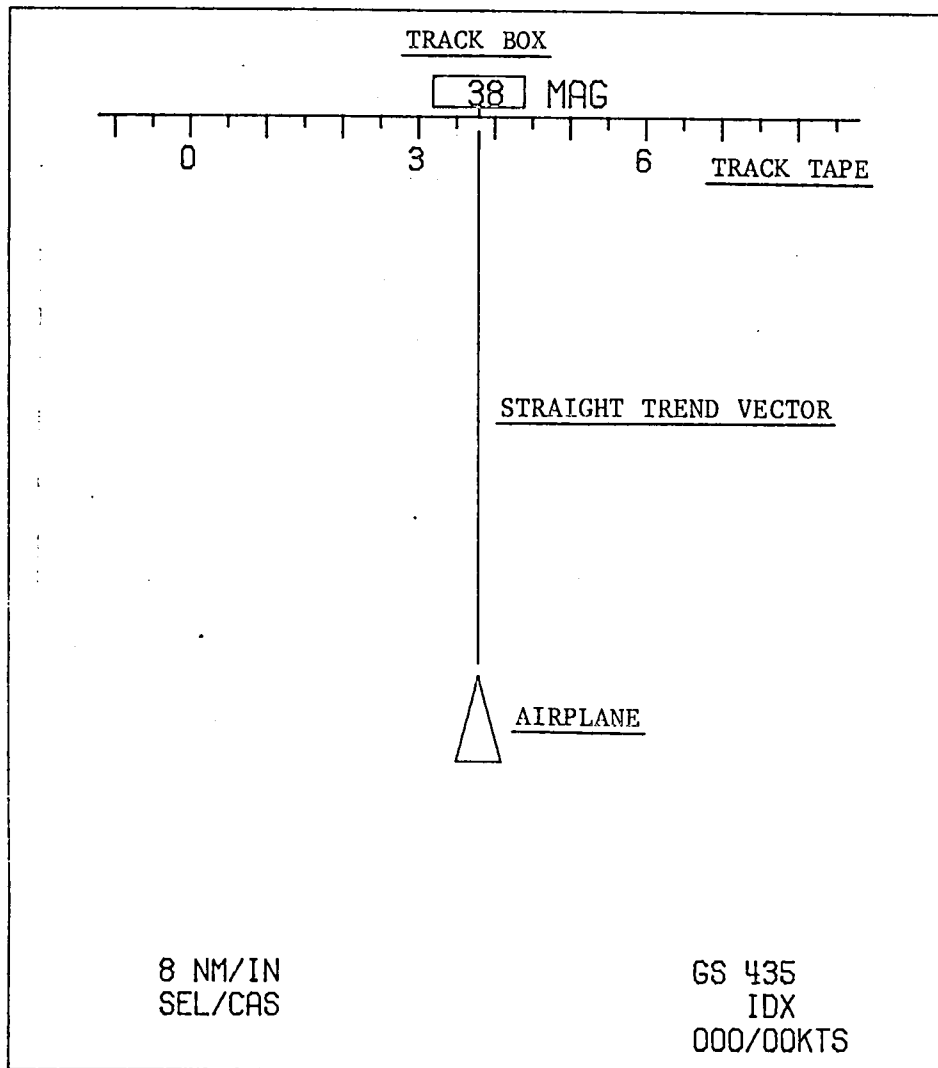
and correctly relate the EHSI display response to aircraft navigation and control.



The Electronic Horizontal Situation Indicator (EHSI), is the name given to the cathode ray tube or CRT, on which the symbols which will be discussed here are displayed. Both the pilot and the copilot are provided with this instrument.



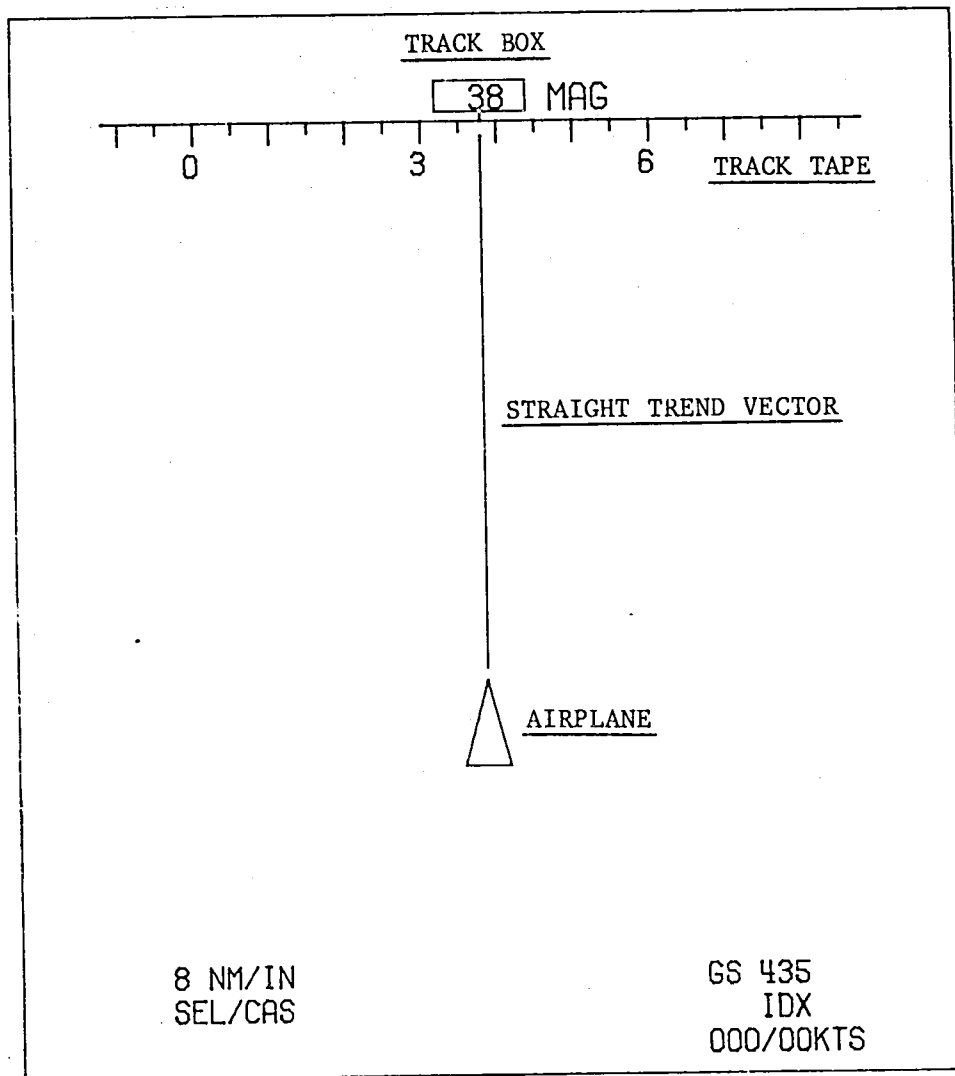
The EHSI mode control panel is the name given to the panel which allows selection of the various symbols presented on the EHSI. Both the pilot and the copilot are provided with panels thus allowing independent control of each display. The panel is composed of three sections: (1) Two columns of push on/push off switches which control display of specific symbols. The switch will illuminate green when engaged, (2) A map orientation selection switch which allows for TRACK-UP or NORTH-UP operation, and display test function, and (3) A map scale switch which allows selection of map scales from 1 nautical mile to 32 nautical miles per inch.



The EHSI symbology provides the pilot with a wide range of information. We will start with the basic display which is displayed at all times and consists of the airplane symbol, the straight trend vector symbol, the track box and track tape symbols, and the various display annotations.

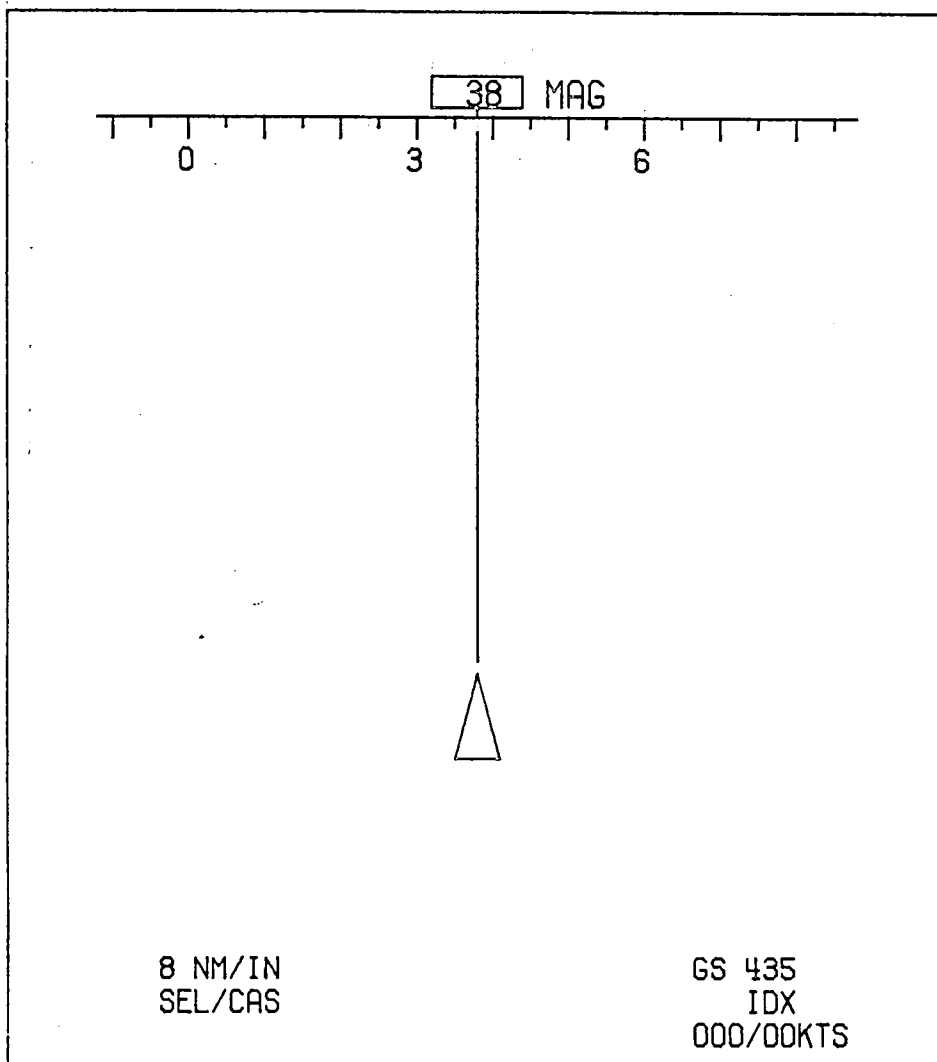
The airplane symbol is a triangle whose apex represents the current estimate of present airplane position. The axis of symmetry of the triangle is always aligned with the current track angle of the airplane.

The straight trend vector symbol is a straight line drawn ahead of the airplane symbol along its axis of symmetry. This line is a prediction of the path the airplane will follow, assuming the current track angle is maintained. This symbol is particularly useful in flying directly to points

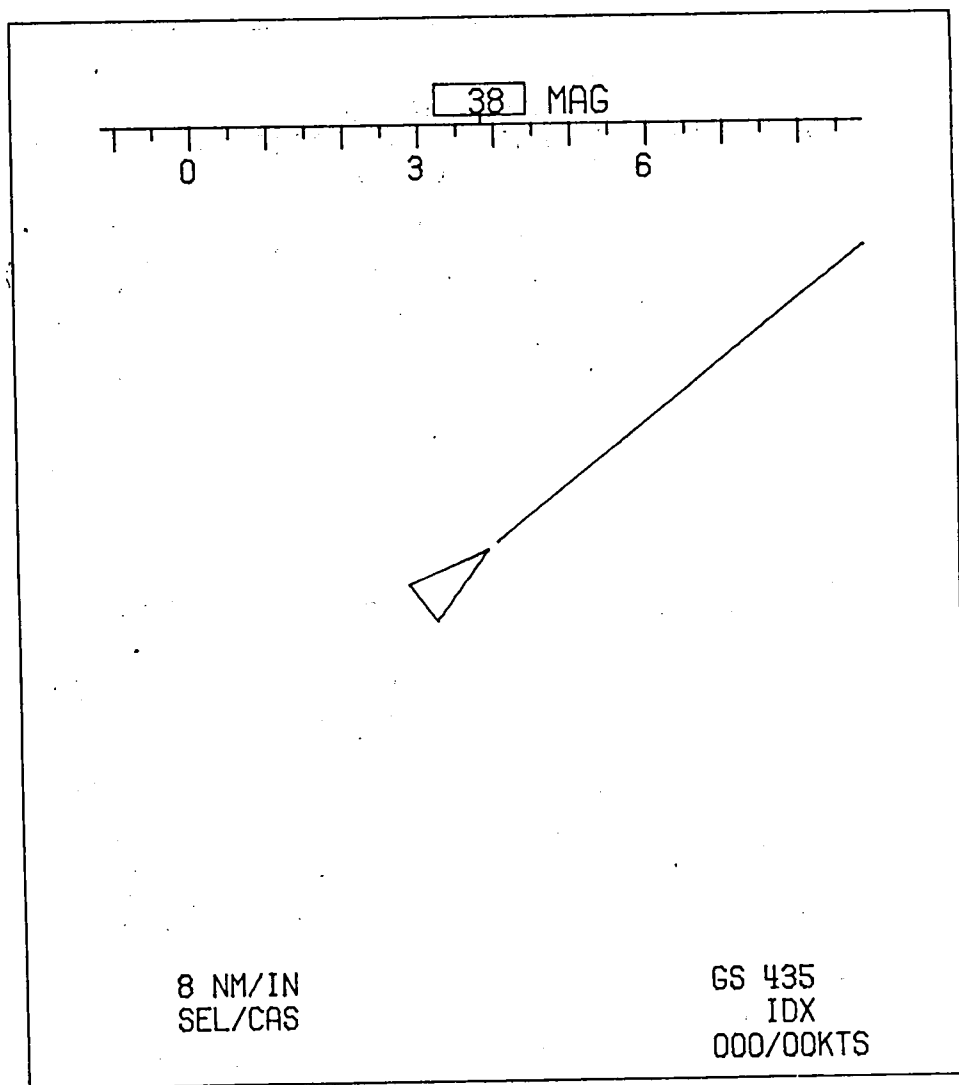


within the display area and in intercepting a planned flight path.

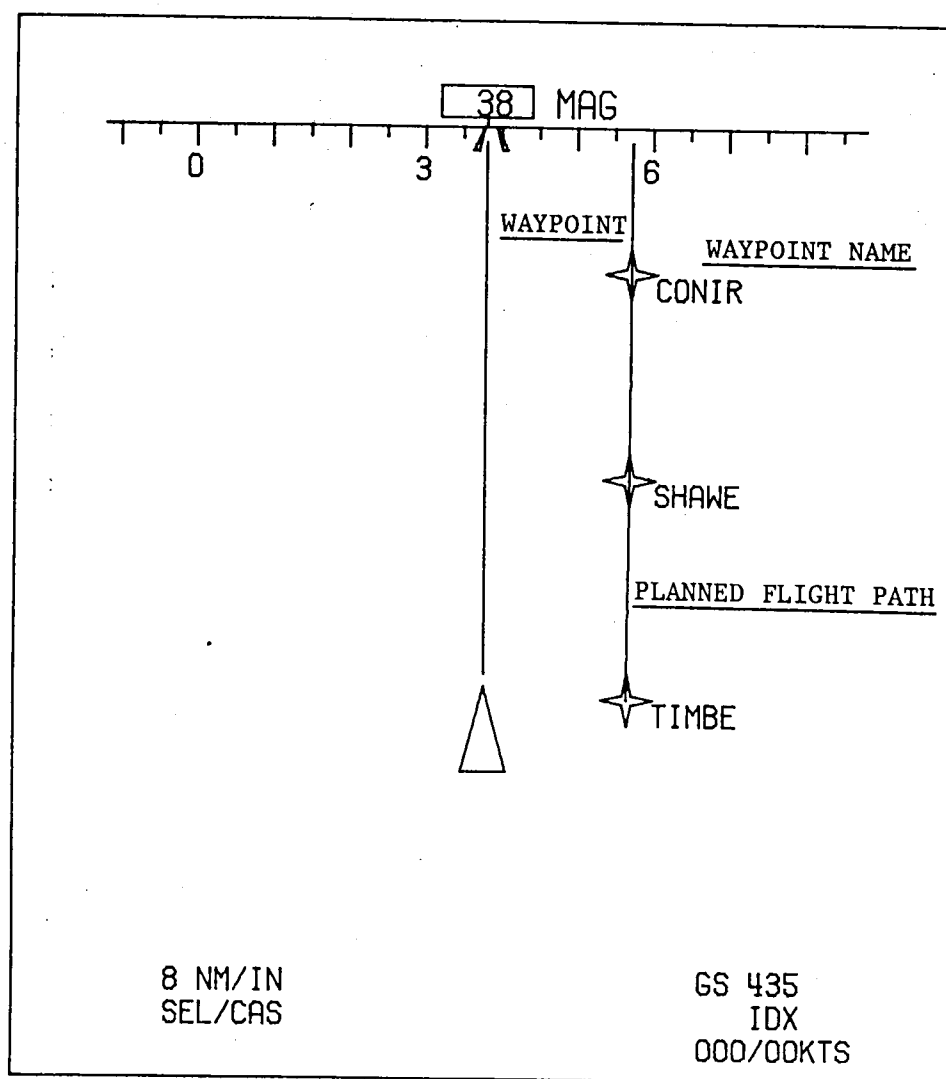
The track box and track tape symbols present the current value of magnetic track angle. The track box gives the current track angle to the nearest degree. The track tape is numbered every 30 degrees and includes major indices at every 10 degrees and minor indices at every 5 degrees. The final zero is not displayed on any of the track tape numerations; that is, 3 means 30 degrees.



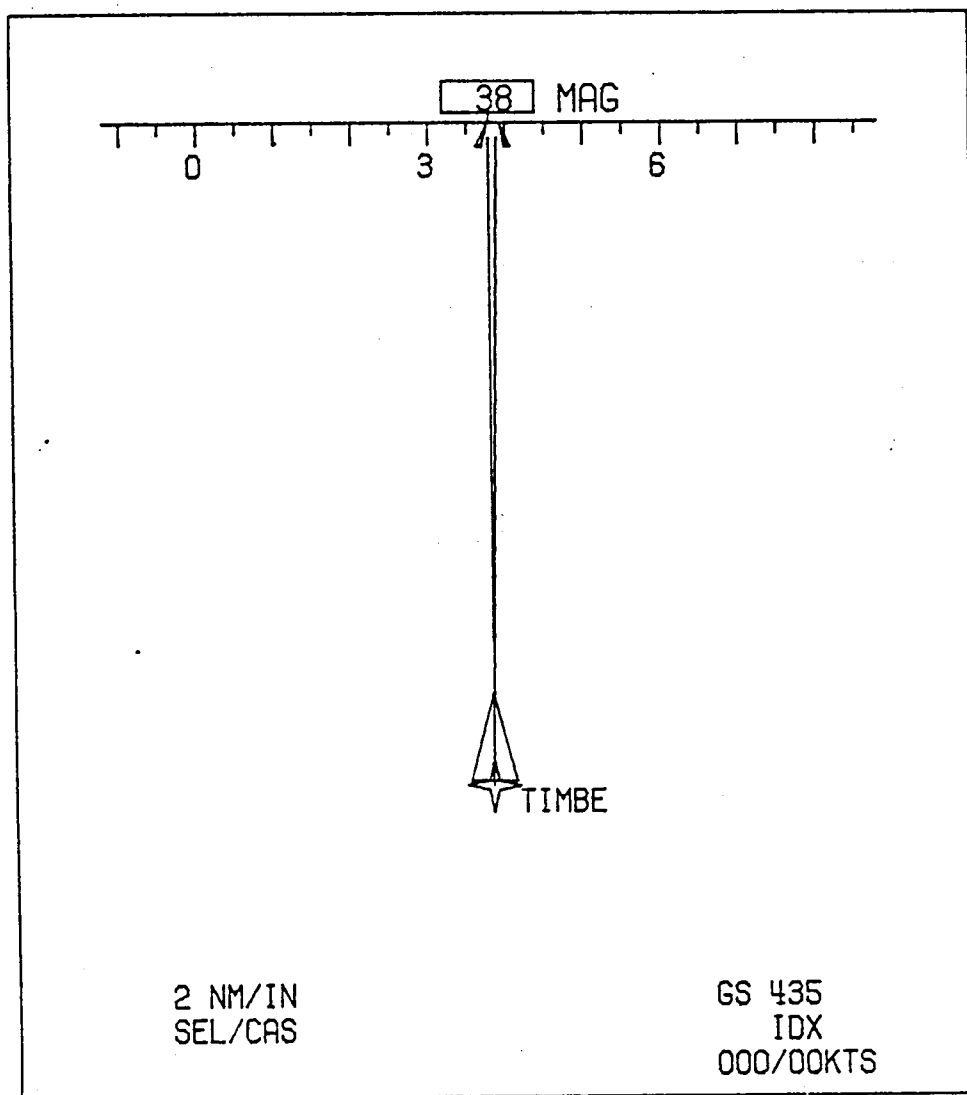
The EHSI has two basic modes of operation, TRACK-UP and NORTH-UP, which are selectable on the mode control panel. The TRACK-UP mode, presented above, is the normal operating mode in flight. In this case, the map is oriented such that the apex of the airplane symbol, which is the airplane's position, is located 1/3 of the distance from the bottom of the display, and the airplane's current track angle is directed toward the top of the display. The map rotates and translates with respect to this point as the airplane maneuvers.



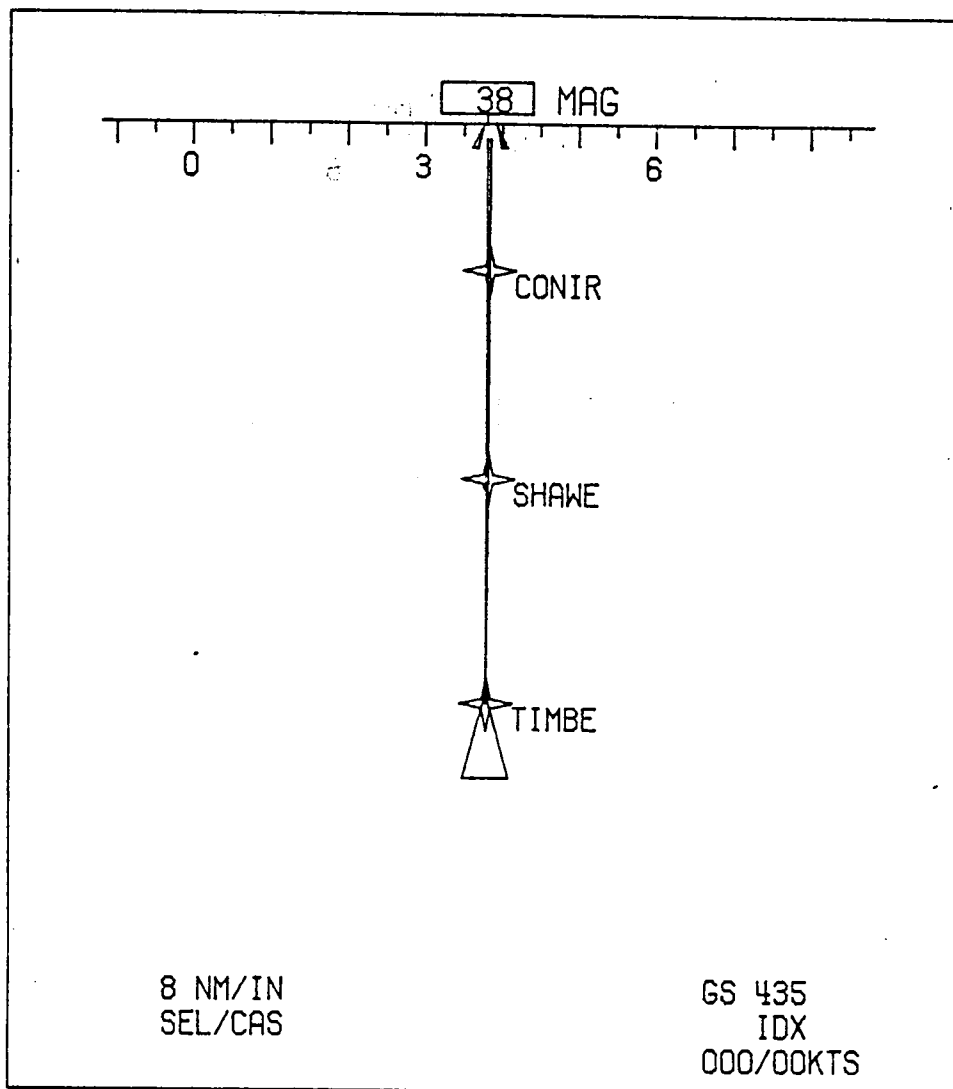
The NORTH-UP mode is used primarily for planning and general orientation, and orients the map display so that true north is at the top of the display. The display is normally centered on the next waypoint of the flight plan. The airplane symbol will be shown in its correct orientation and position against the fixed map background so long as its present position is within the display area. If the present position is outside the display area, the airplane symbol will remain within the display boundary with its correct orientation. The symbol will be positioned along a line between the display center and its actual position. Whenever the airplane symbol is limited in this manner, the straight trend vector will be blanked.



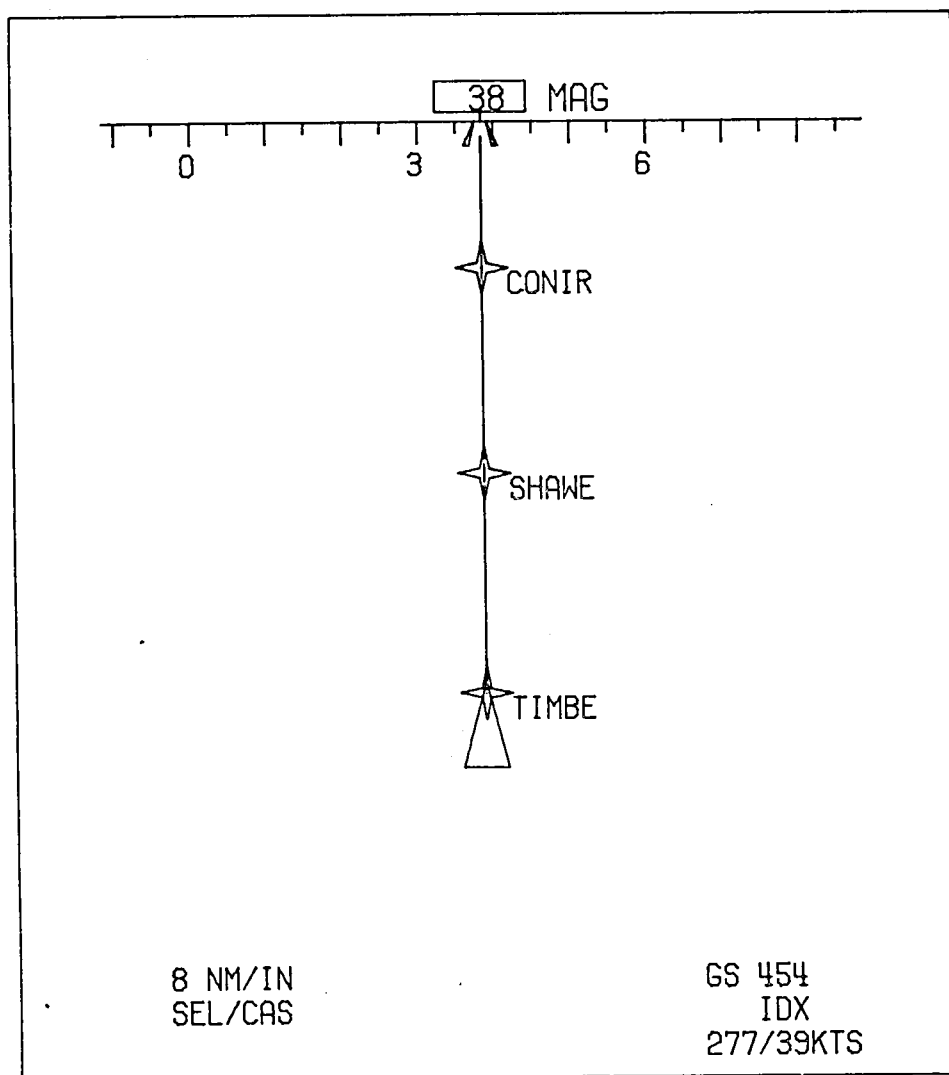
The planned flight path is displayed as a series of straight line segments connected by circular arcs. Waypoints, which are points of importance along the planned flight path, are identified by a four-pointed star symbol and a three-to five-character designation representing the name of the waypoint. Prior to activation of the planned flight path in the navigation computer by the pilot, the flight plan data entered are considered to comprise a provisional path which appears as a dashed line on the display. After activation of the flight plan, the dashed line turns to a solid line.



Six different map scale factors are provided for the EHSI map display. These scales are 1, 2, 4, 8, 16, and 32 nautical miles per inch and are selectable by means of the rotary switch on the mode control panel. The pilot and the copilot may have different map scales selected for their respective EHSI's. Pictured above is a section of a route displayed on the 2 nautical mile per inch scale.



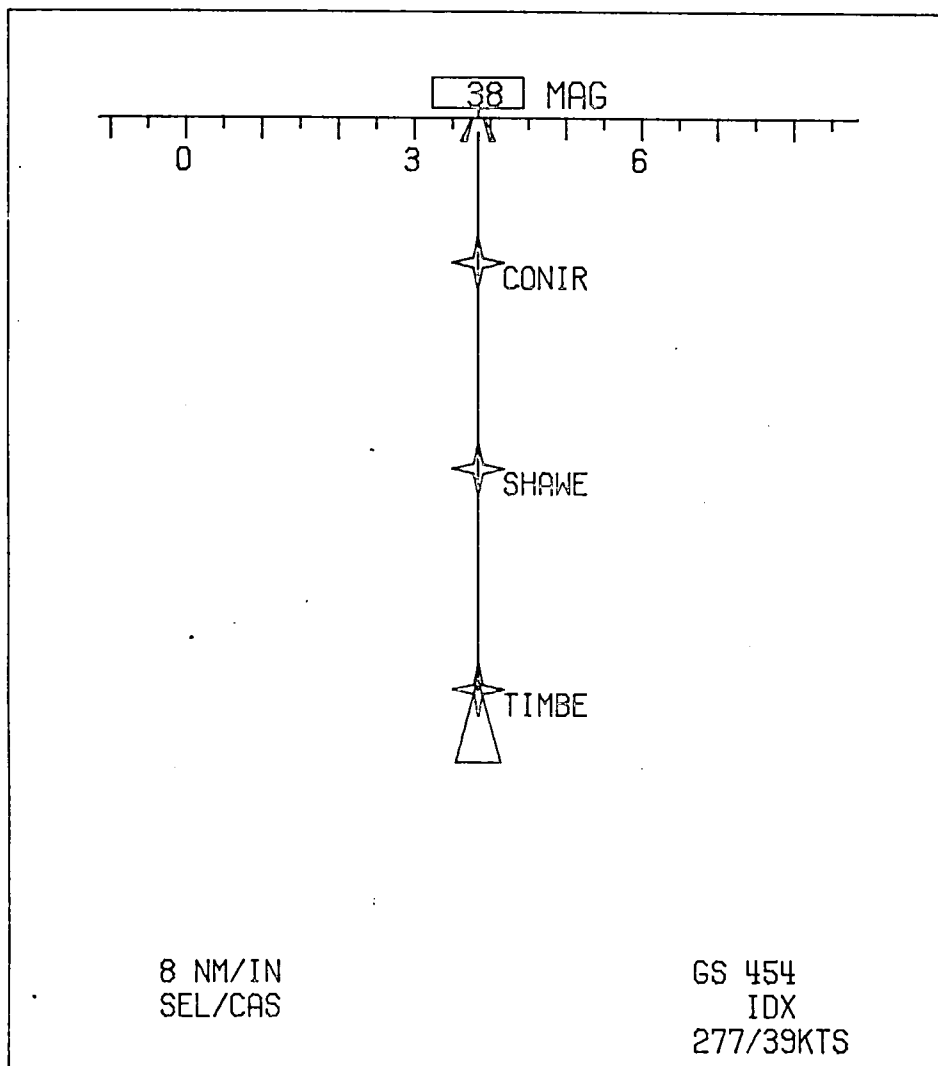
Here the route is displayed at 8 nautical miles per inch. The pilot tends to use the smaller map scales while maneuvering the airplane and the larger map scales for planning and orientation along the route.



The final part of the EHSI display which is present at all times is the annotation at the bottom of the display. The lower left corner annotation is made up of two lines - the map scale in nautical miles per inch, NM/IN, and the Advanced Guidance and Control System (AGCS) mode. The lower right corner annotation is made up of three lines - the airplane ground speed (GS) in knots, in this case 454 knots, the navigation position estimate update mode, and the current wind conditions.

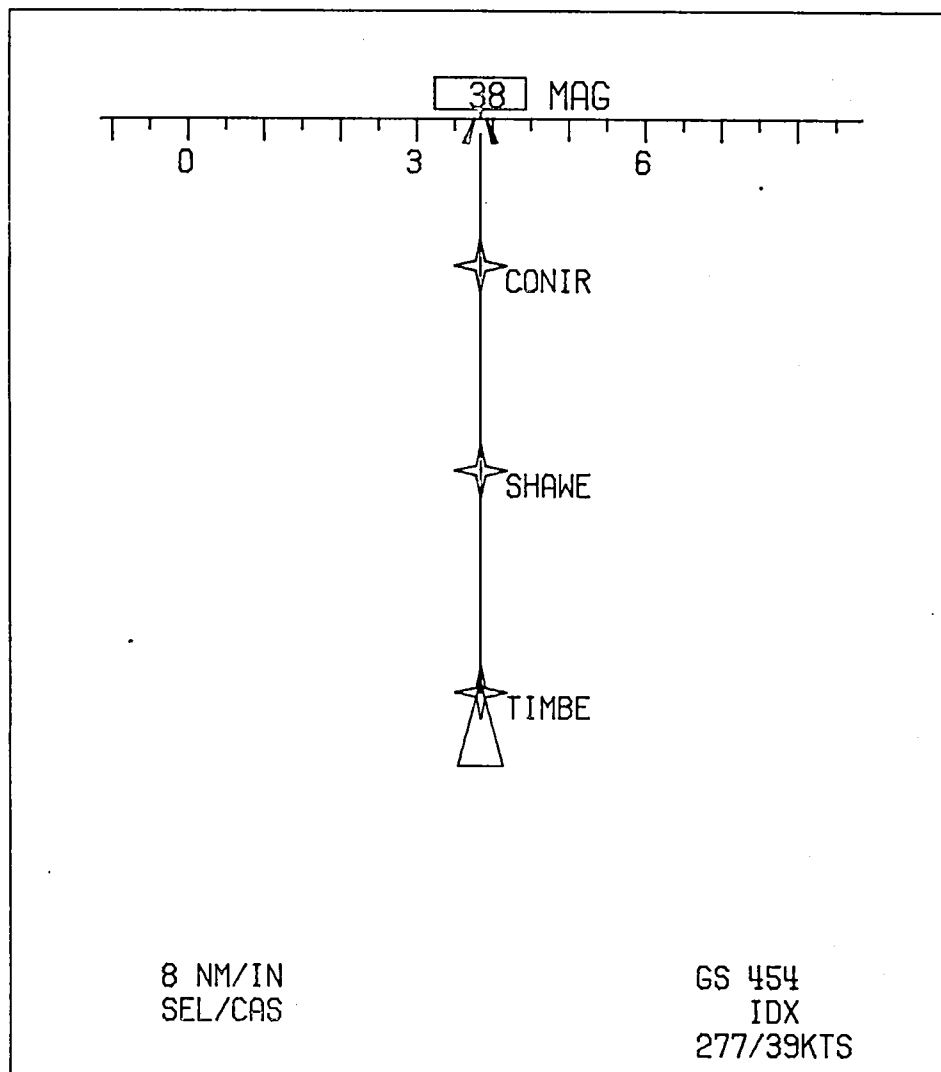
The current AGCS mode engaged will be displayed in the lower left corner of the display. If no mode is selected, or if control wheel steering only is engaged, this line will be blank. The following notations are used to represent the various modes:

- G2D - horizontal path is selected
- G3D - horizontal path and vertical path are selected



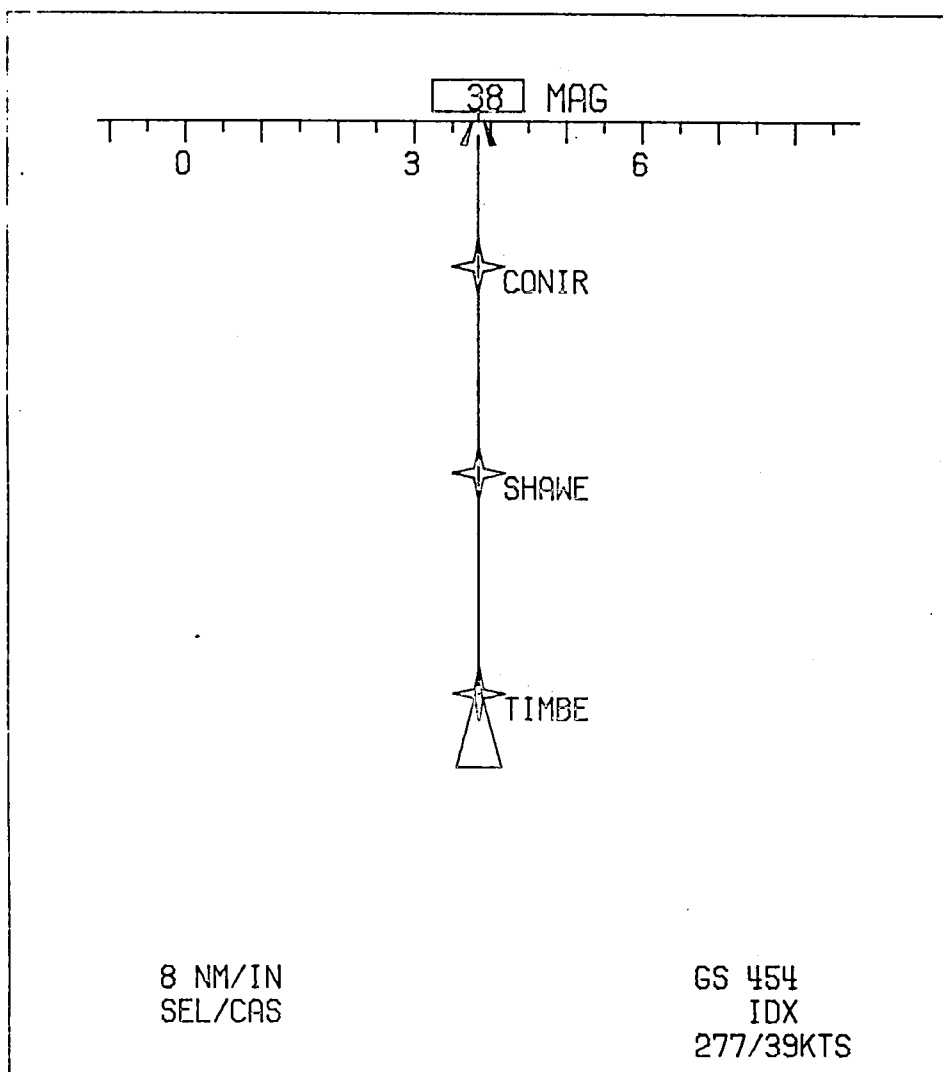
- G4D - horizontal path, vertical path, and time path are selected
- LAND - autoland is selected
- SEL/___ /___ /___ - this indicates that a select/hold mode has been selected. At least one three-letter group following SEL/ must be shown. Up to three nonexclusive modes may be displayed at a time. The three-letter select/hold abbreviations are
- TKA - track angle select
 - FPA - flight path angle select
 - ALT - altitude hold engage
 - CAS - calibrated airspeed engage (autothrottles engage)

The display above indicates a manual control mode in use, such as control wheel steering, and that calibrated airspeed engage or autothrottles, has been selected.



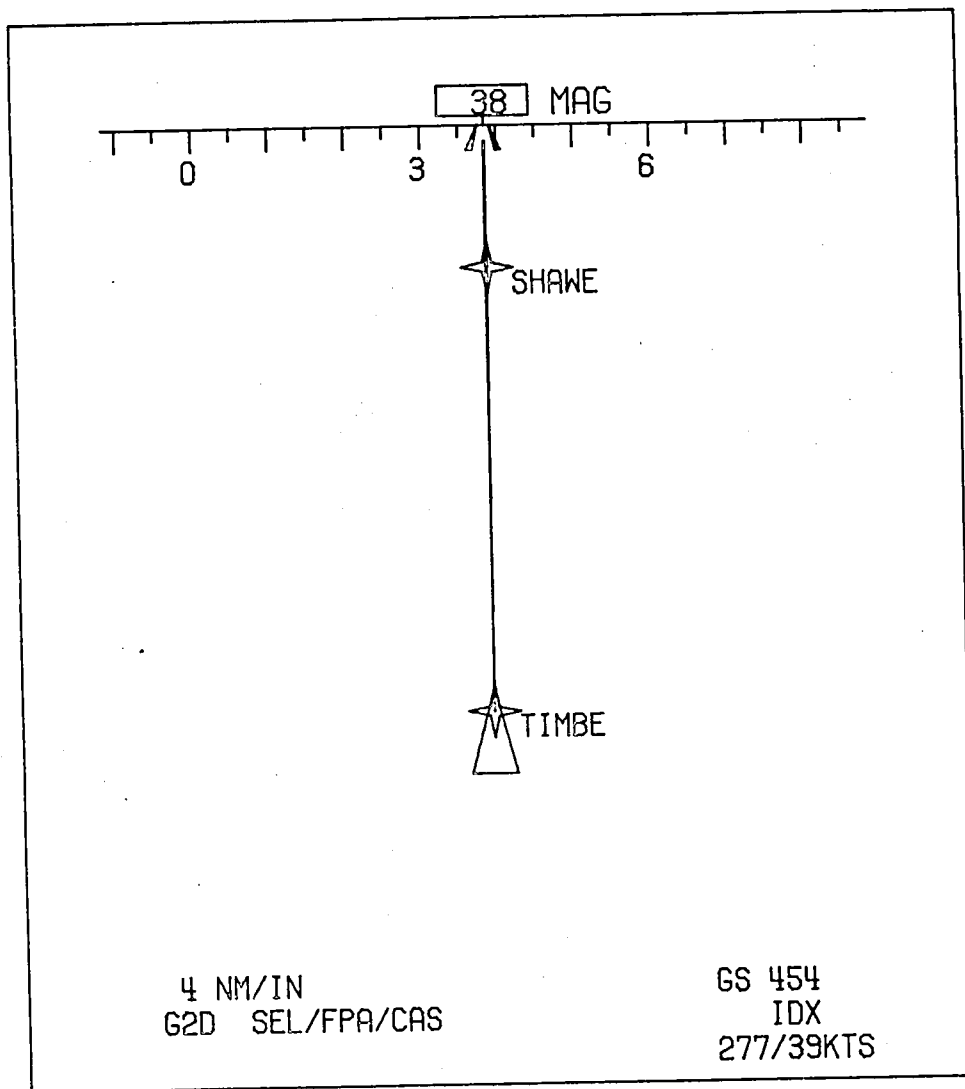
The navigation position estimate update mode, which indicates the type of input used to estimate the airplane's position, will be displayed in the lower right corner of the display and is represented by a three-letter designation. These letters indicate the source of navigation information currently being used by the computer and have the following definitions:

1st letter	I - inertial data
	A - air data
	X - none
2nd letter	D - DME #1
	V - VOR #1
	L - ILS
	M - MLS
	X - none
3rd letter	D - DME #2
	V - VOR #2
	X - none



The following 2nd and 3rd letter combinations are prohibited: VV, VX, and XV. The display above shows the navigation mode as inertial data, DME #1, and none.

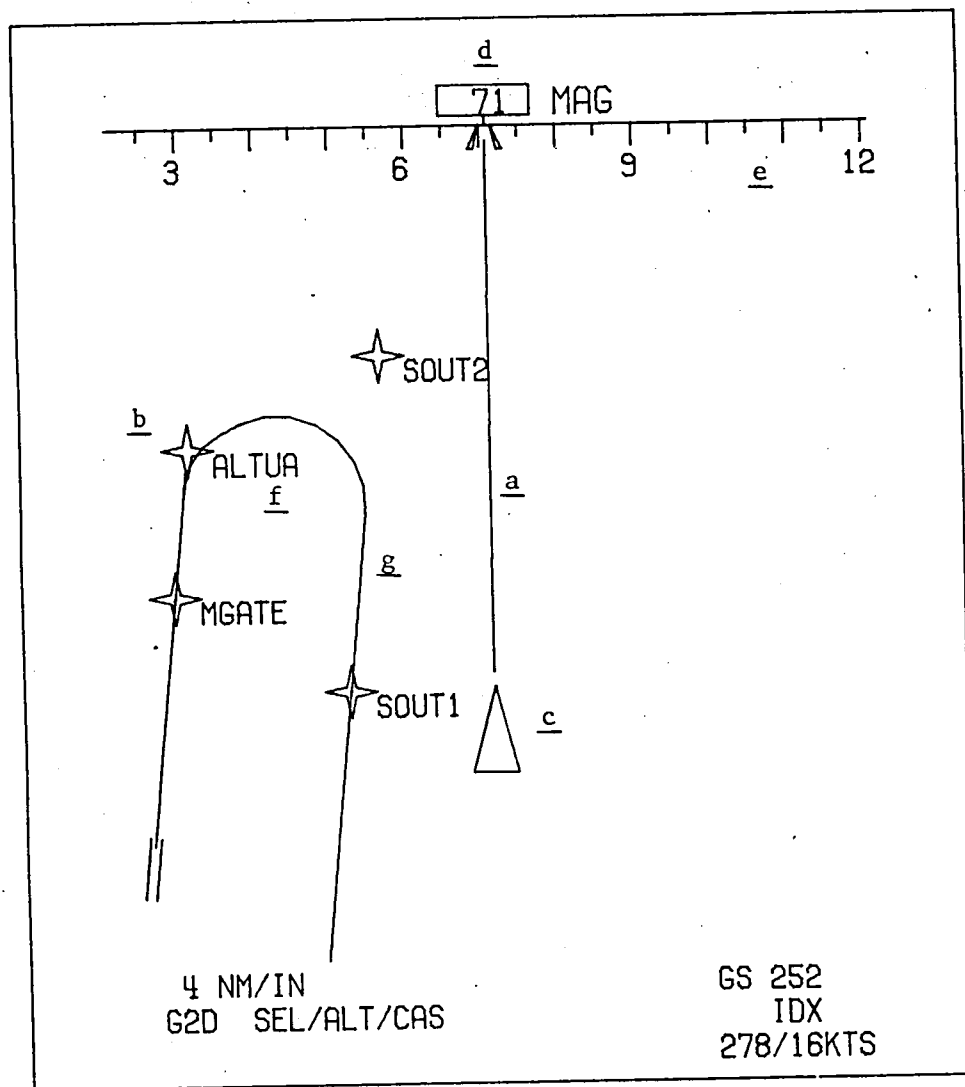
The current wind conditions are displayed in the lower right corner of the display. The conditions are displayed as "direction/velocity", with the direction in degrees magnetic and the velocity in knots. The display above shows a wind with a direction of 277° magnetic at 39 knots.



In this example, the display indicates a map scale of 4 nautical miles per inch; an AGCS mode consisting of horizontal path (G2D) , flight path angle select (FPA), and calibrated airspeed engage (CAS); a ground speed of 454 knots; a navigation mode consisting of inertial data, DME#1, and NONE; and a wind condition of direction 277° magnetic and velocity 39 knots.

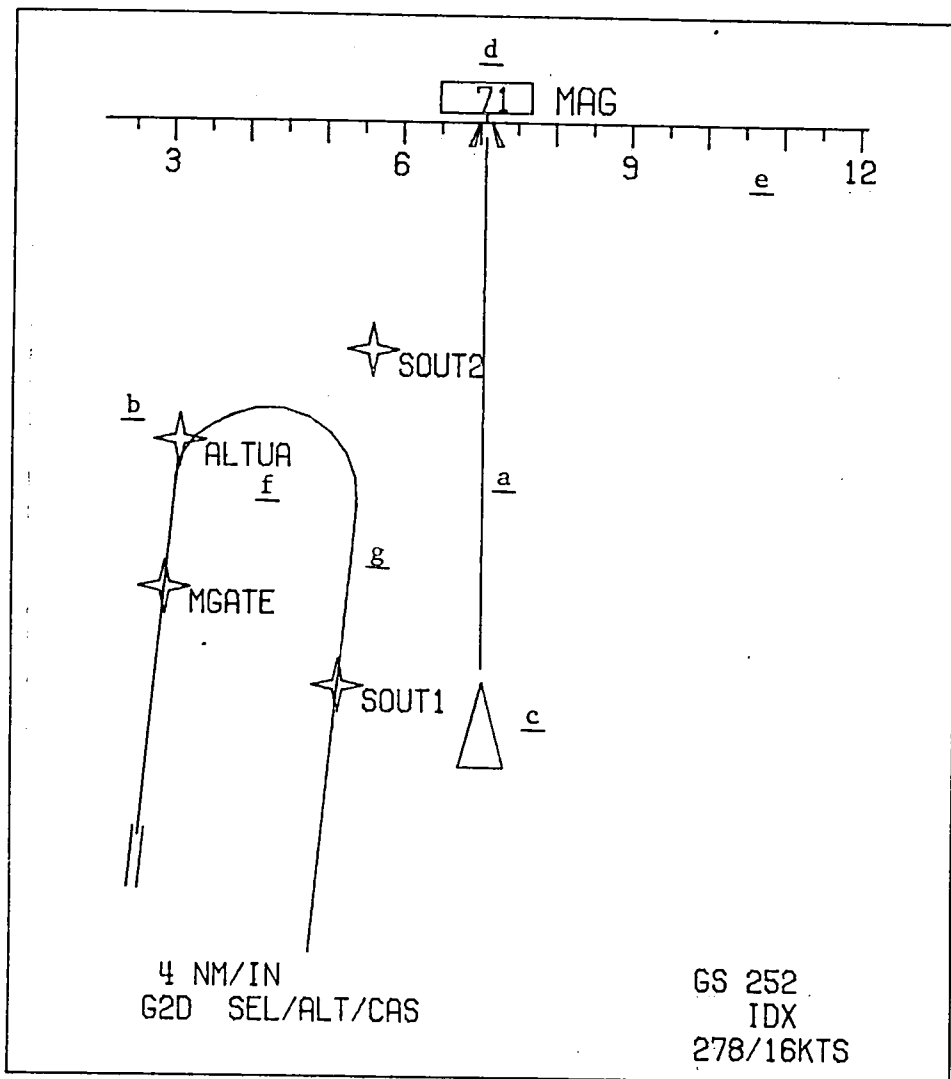
QUIZ

Now, let's have a short quiz of the symbols covered so far. Make certain that you have your test sheet or a piece of paper and pencil handy.



Identify the symbols labeled a through g and answer the following questions:

- (1) Is the display in the NORTH-UP or TRACK-UP mode and what is the airplane's track angle?
- (2) What waypoint is the airplane passing?
- (3) What is the map scale set at?
- (4) What is the wind direction and velocity?
- (5) What AGCS mode is selected?
- (6) What is the ground speed?
- (7) What navigation mode is in use?

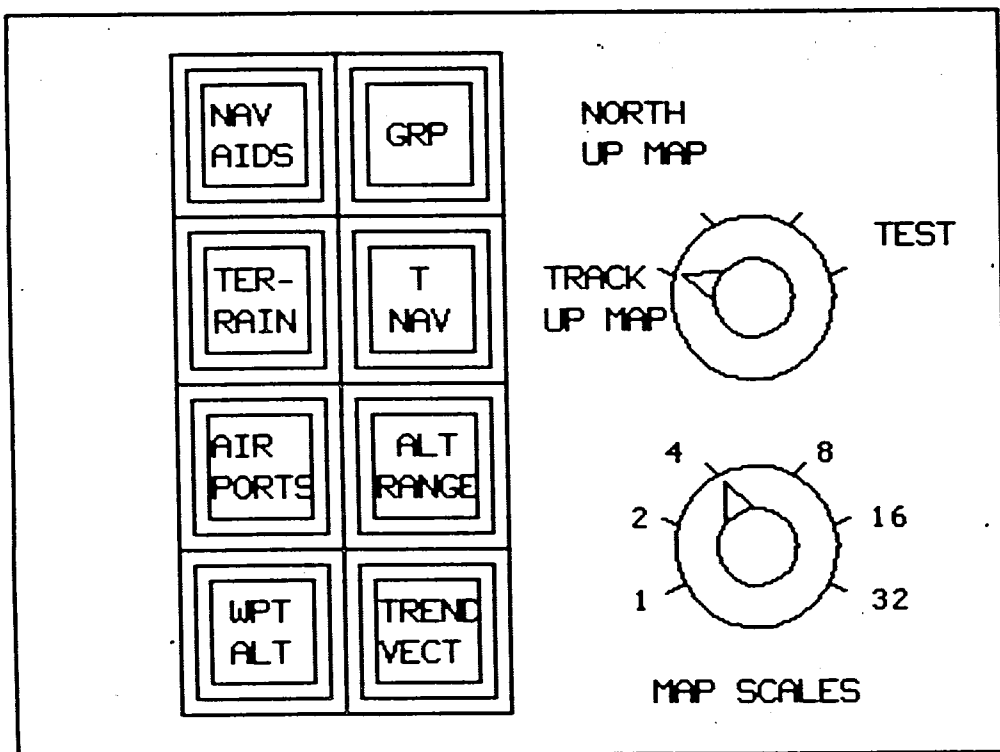


Here are the correct answers

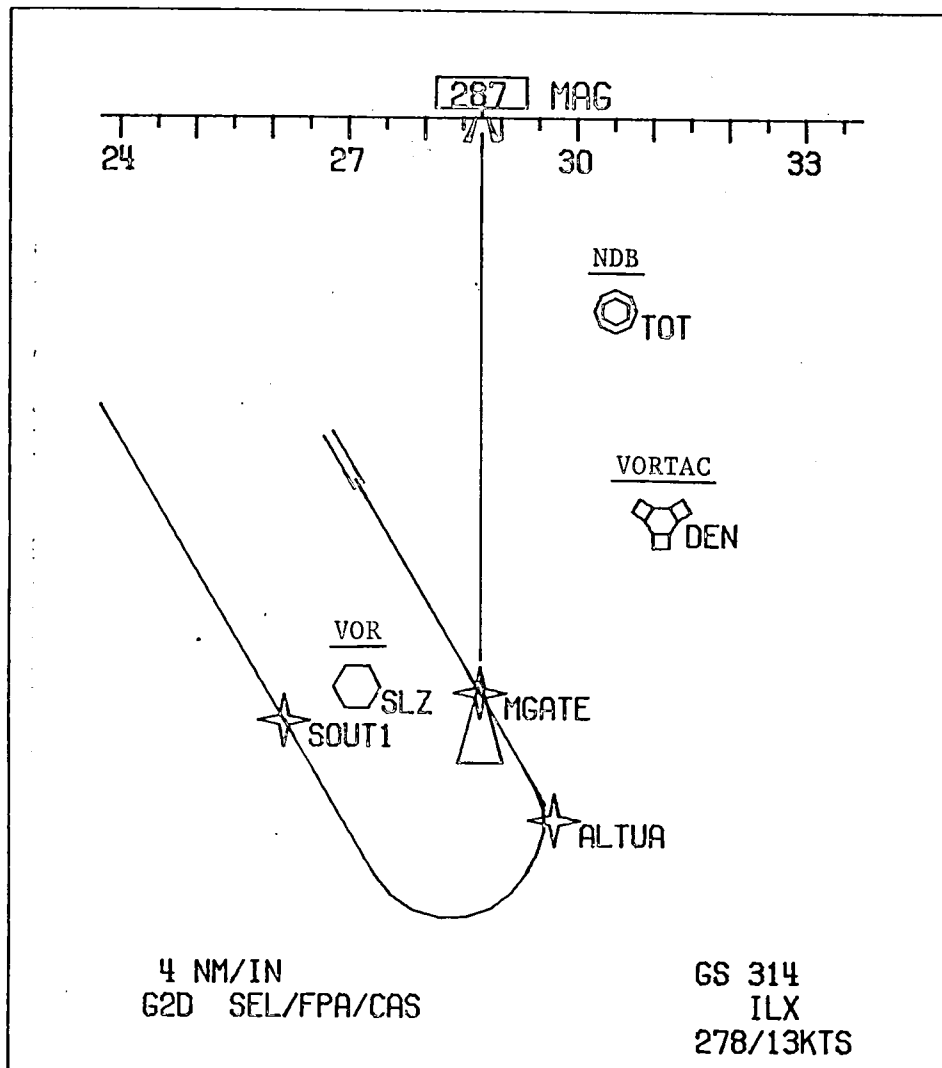
- | | |
|---------------------------|-------------------------|
| (a) straight trend vector | (e) track tape |
| (b) waypoint | (f) waypoint name |
| (c) airplane | (g) planned flight path |
| (d) track box | |

- (1) TRACK-UP, 71° magnetic
- (2) SOUT1
- (3) 4 nautical miles per inch
- (4) 278° magnetic, 16 knots
- (5) horizontal path, altitude hold engage, calibrated airspeed engage
- (6) 252 knots
- (7) inertial data, DME#1, None

After you have checked your answers, proceed with the next section. If you did not answer each question correctly, go back and review the appropriate text.



This section deals with the symbols which can be selected by use of the switches located on the EHSI mode control panel. The switches are arranged in two columns as represented here and will illuminate green to indicate on.

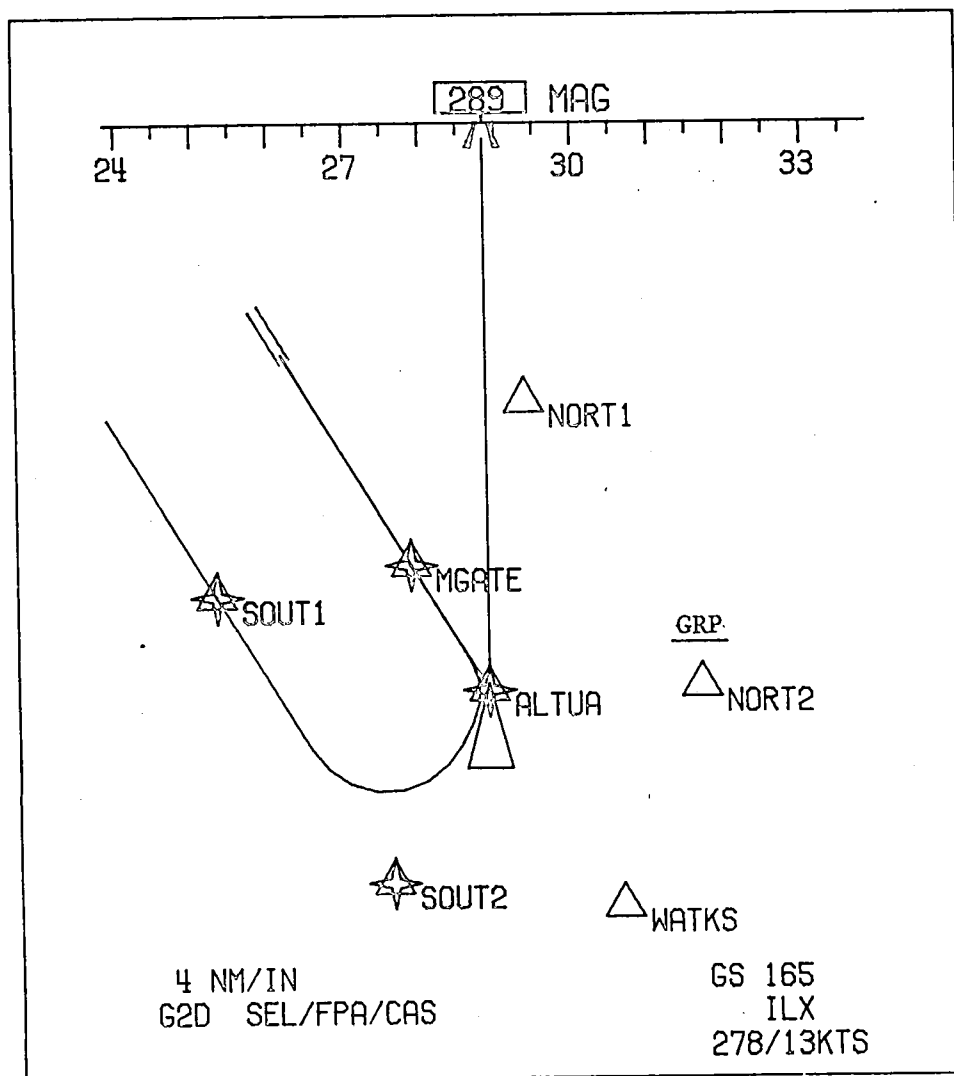


The EHSI display pictured introduces the radio aid symbols which are used to identify the type and location of ground-based radio navigation aids which may be of interest to the pilot. A three-character alphanumeric designation is displayed with each symbol to identify the station. All radio aid symbols within the viewing area of the display may be selected or deselected with the NAV AID option switch. Radio aids used for flight plan waypoints and those used for navigation position estimate updates are displayed regardless of NAV AID option selection. The symbols fall into the following types:

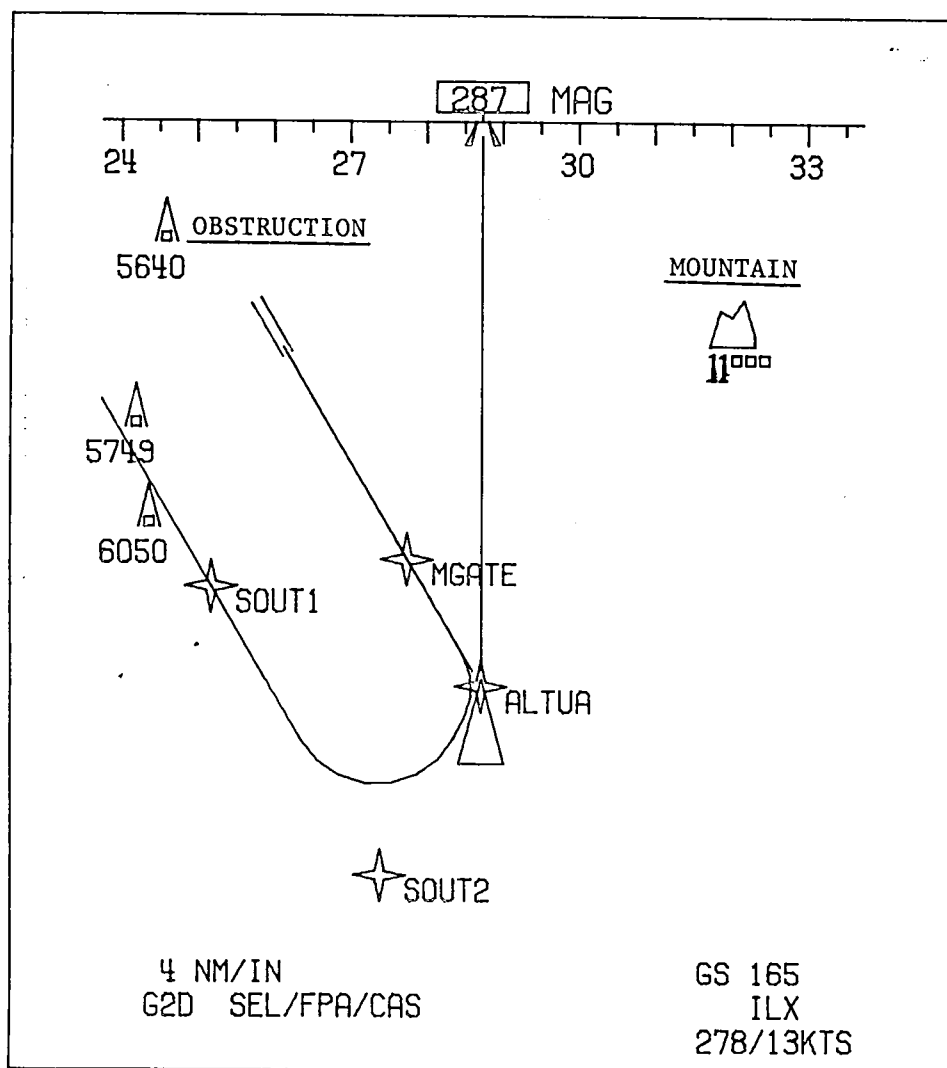
NDB (Nondirectional Radio Beacon) Symbol- these stations are not used by the navigation computer, but may be used by the pilot using onboard ADF (automatic direction finding) equipment.

VOR Symbol - very high frequency omnidirectional range radio aid

VORTAC Symbol - colocated VOR and TACAN (tactical air navigation) radio aids. Also used for a VOR radio aid with paired DME (distance measuring equipment) or VOR-DME, and DME alone.



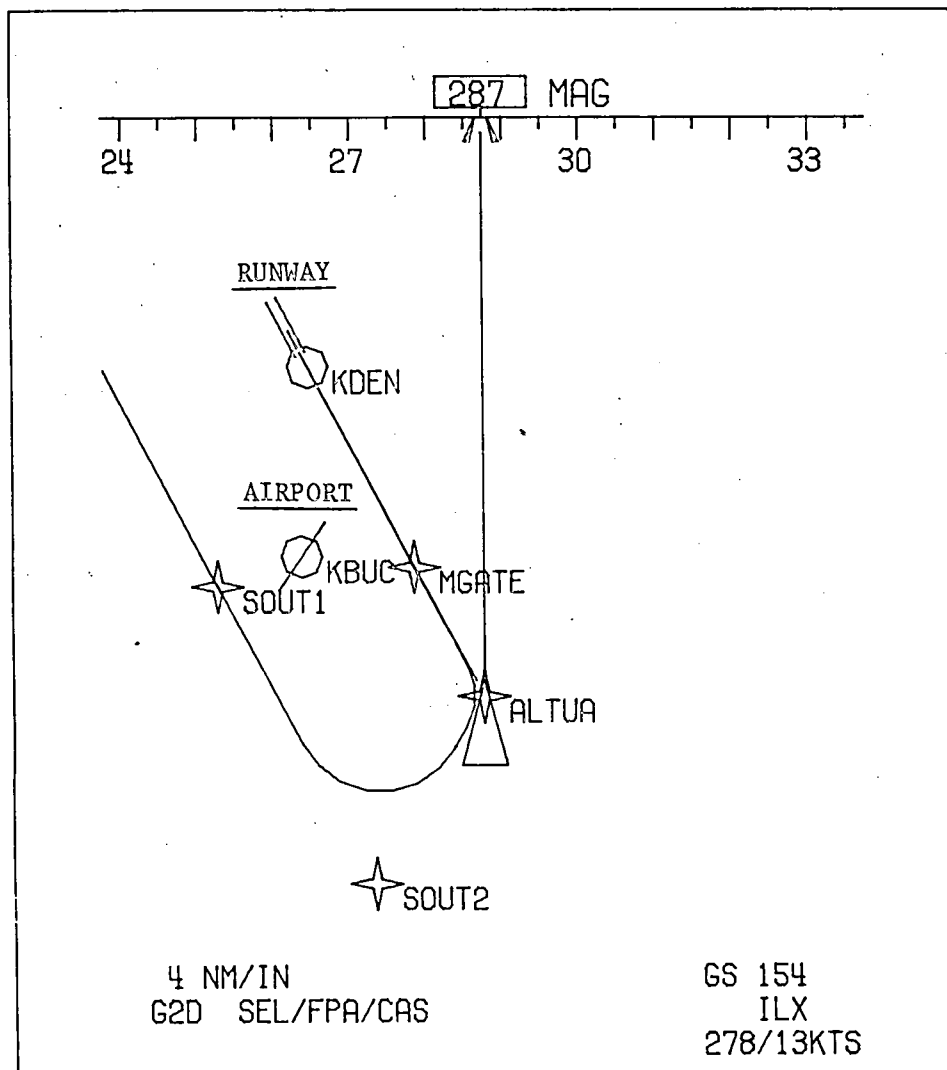
The EHSI display pictured introduces the geographic reference point (GRP) symbol which is selected or deselected by use of the GRP option switch. This symbol locates points of interest other than navigation aids, terrain, or airports. Normally geographic reference points are ATC designated points commonly used in the control of aircraft, for example, intersections. A five-character alphanumeric designation is used to identify the geographic reference points.



This display introduces the prominent terrain feature symbols which are selected or deselected by use of the TERRAIN option switch. The terrain feature symbols are composed of obstruction symbols and mountain symbols.

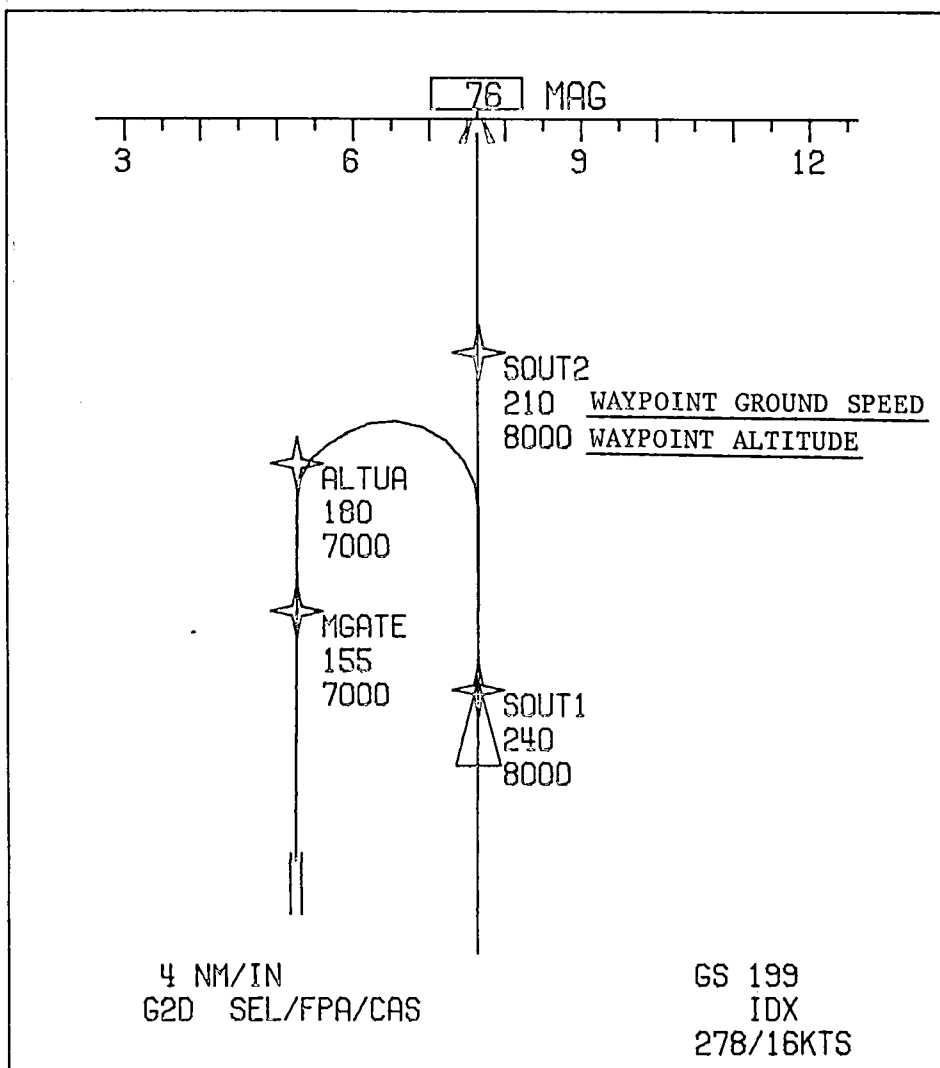
The obstruction symbol indicates an obstruction or hazard in the take-off or approach paths to an airfield. The symbol includes a tag showing the elevation above sea level of the obstruction.

The mountain symbol indicates the location and elevation above sea level of prominent high terrain points. The elevation shown is the actual elevation of the feature rounded to the next higher thousand feet.

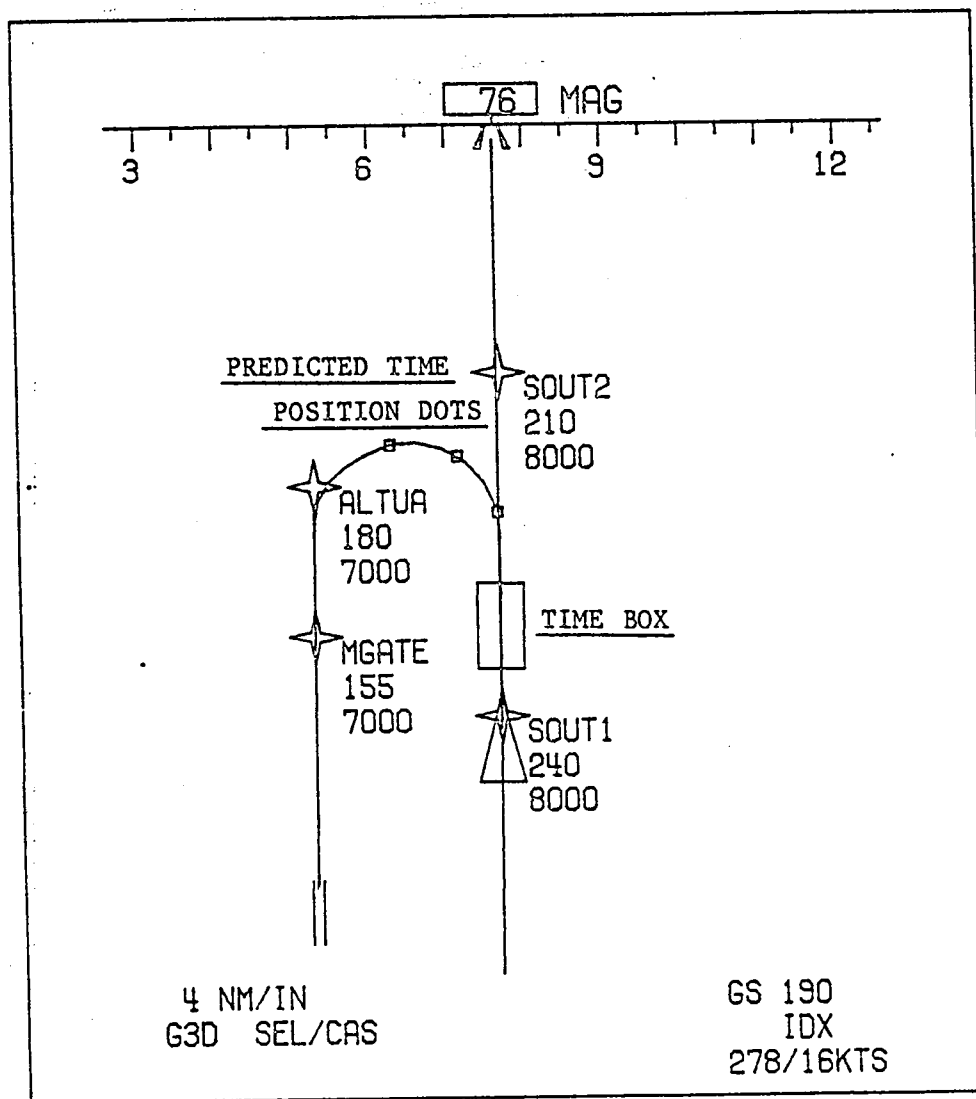


This display introduces the airport and runway symbols. The AIRPORT option switch selects or deselects display of the location, primary instrument runway orientation, and four-letter ICAO designation for all airports within the map area which have been stored in the navigation data. The departure and destination airports designated in the flight plan will be displayed regardless of the position of the AIRPORT switch.

The departure and destination runways are represented by a double solid line whose orientation is directly related to the actual runway. This symbol is used with map scales of 1, 2, and 4 nautical miles per inch. The airport symbol is used at all other map scales.

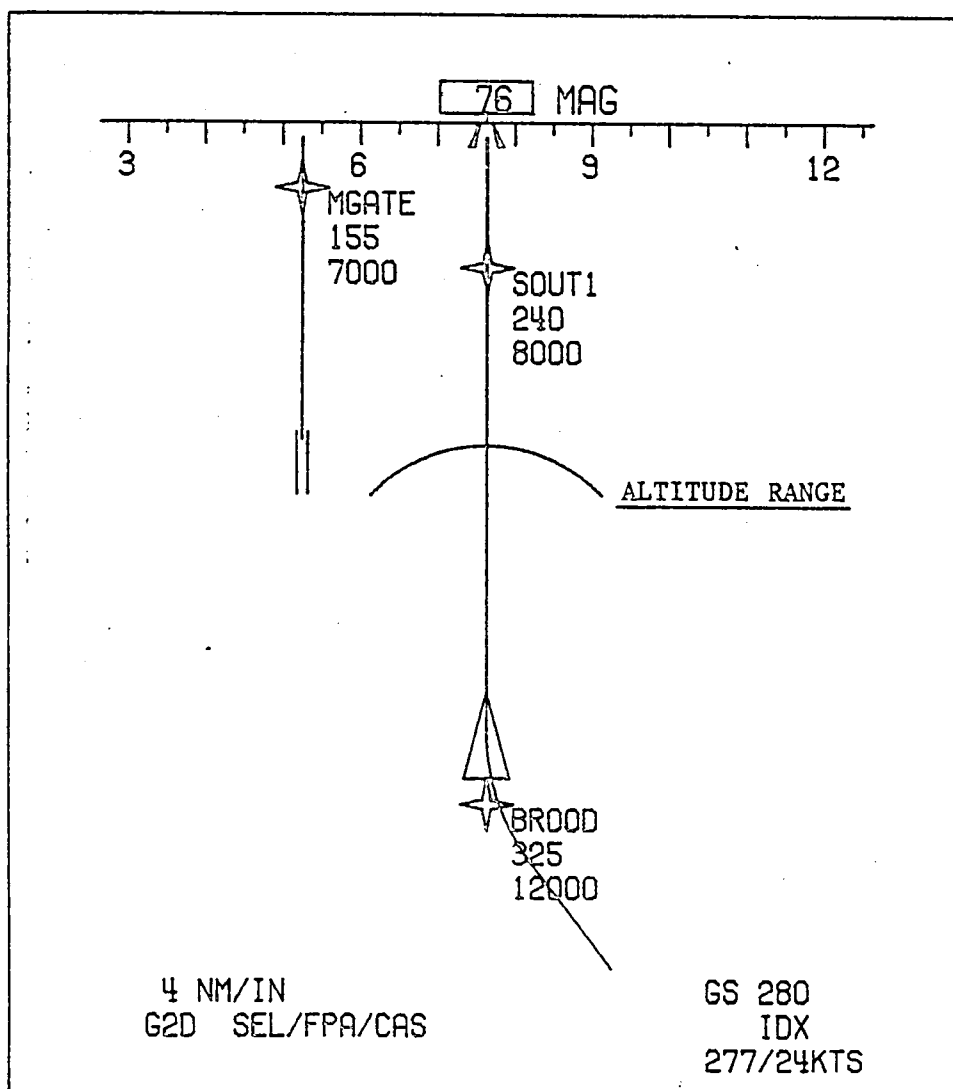


This display introduces the waypoint ground speed and waypoint altitude annotations which are selected or deselected by use of the WPT ALT option switch. The ground speeds, measured in knots, are displayed beneath the waypoint names, and the altitudes, measured in feet, are displayed beneath the ground speeds. These are the values assigned to each waypoint in the flight plan.

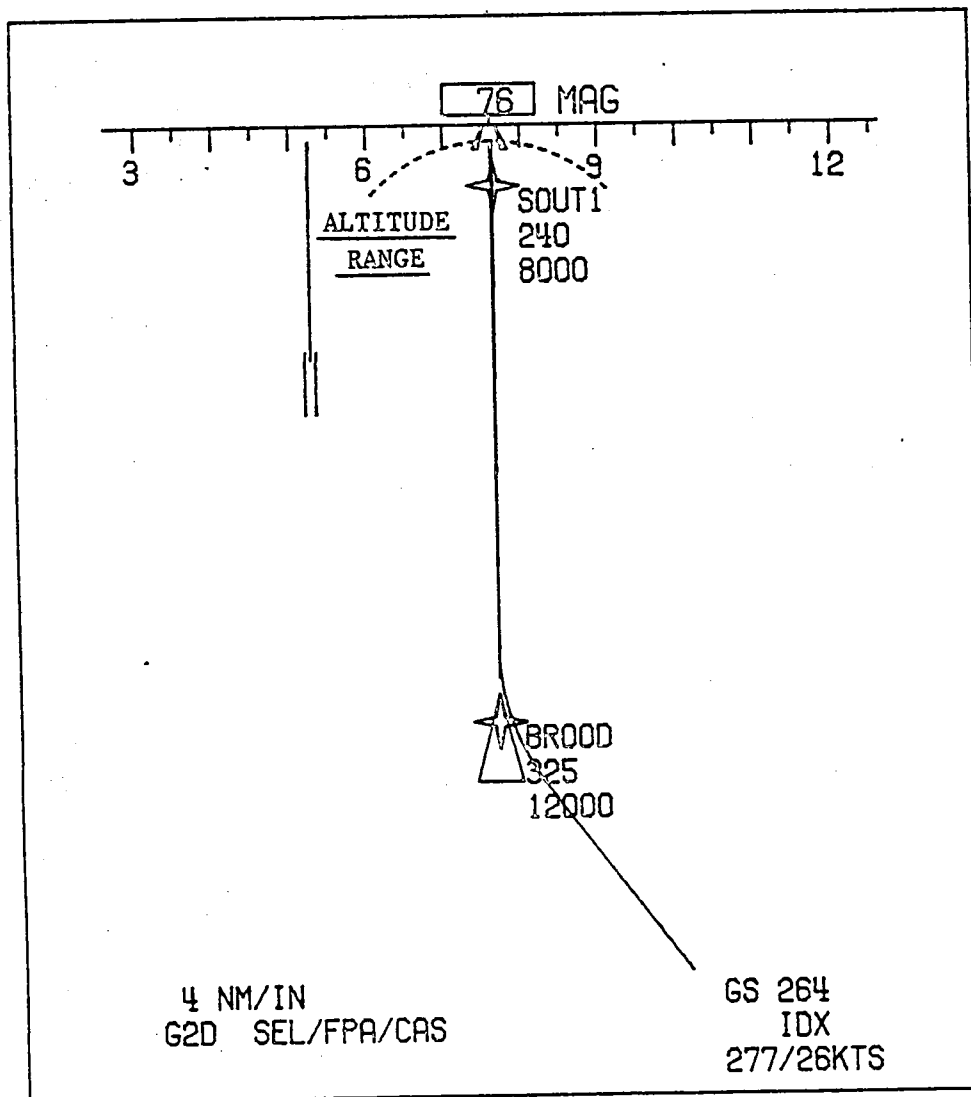


This display introduces the time box and predicted time position dots symbols which are selected or deselected by use of the T NAV option switch. The time box, depicting the planned time position, is available for display when the navigation system is in the 4-D mode, and when a time profile has been defined by assigning a ground speed to each waypoint and a time to one of the waypoints. When the actual airplane position agrees with the planned time position, the time box will enclose the airplane symbol. Thus, the intersection of the leading edge of the time box with the flight plan path is the planned position for the current time.

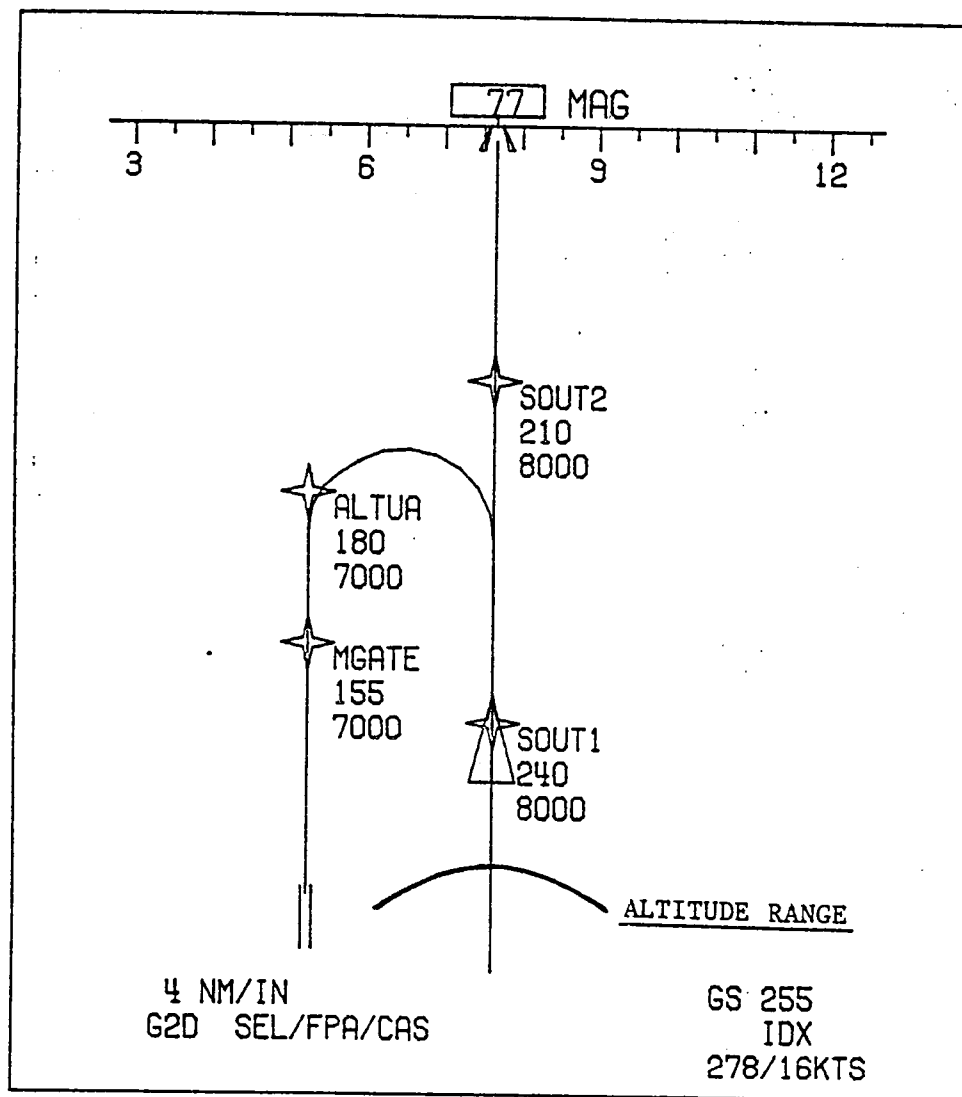
Three small circles, predicted time position dots, are positioned 30, 60, and 90 seconds ahead of the planned time position along the planned flight path. On a constant ground speed path segment, the predicted time position dots will be centered on the ends of the three curved trend vector segments when the airplane is in the planned time position and maintaining the planned ground speed. If the dots are not centered on the ends of the appropriate curved trend vector segments, the pilot can tell that a ground speed change is required.



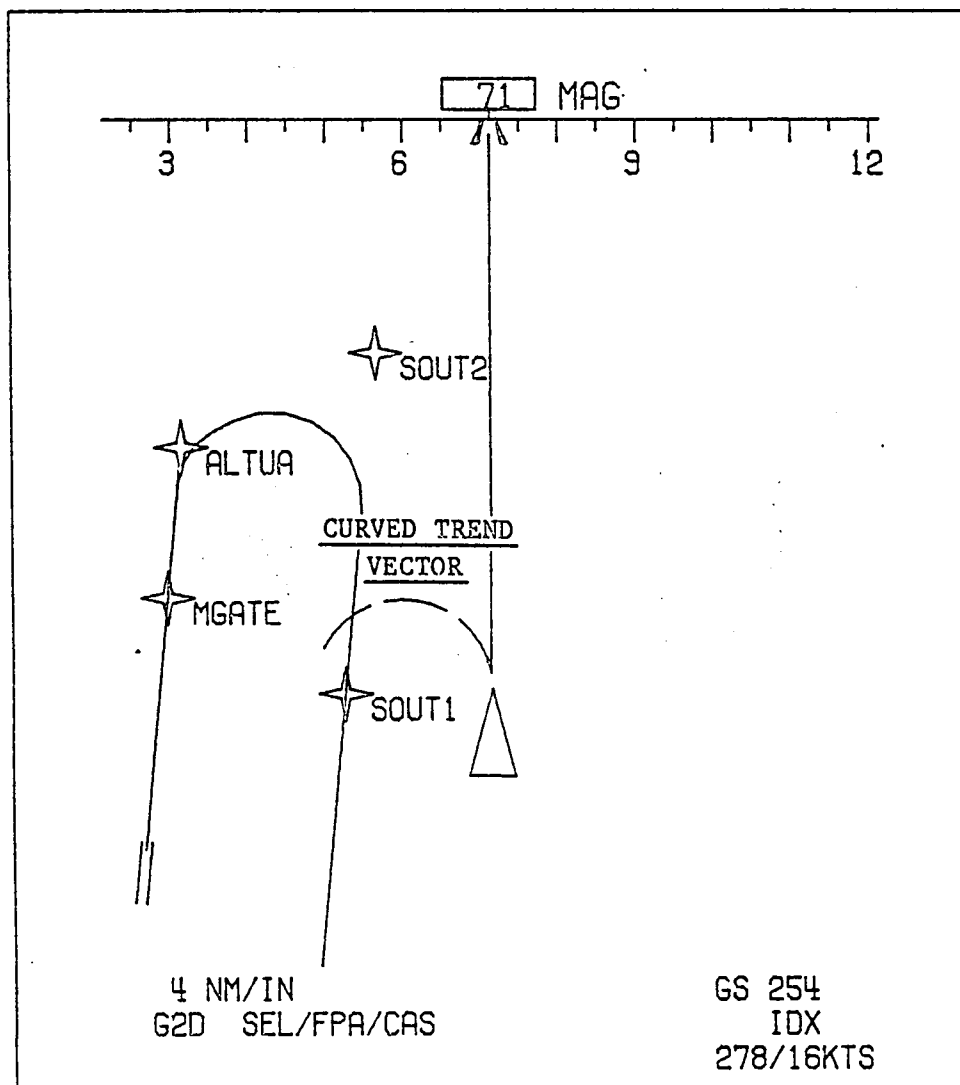
This display introduces the altitude range symbol, an arc, which is selected or deselected by use of the ALT RANGE option switch when the EHSI is in the TRACK-UP mode. The intersection of this arc symbol with the straight trend vector is a prediction of the point over the ground where the airplane would reach a selected altitude, assuming that the current flight path angle and track angle remain constant. If the intercept point is not as desired, the pilot can alter the flight path angle to ensure a satisfactory intercept point. The reference for this symbol is the altitude preselected in the altitude engage readout on the AGCS mode select panel. In this display, the airplane will reach the desired altitude shortly before the SOUT1 waypoint.



If the range to the intercept point exceeds the display area, the altitude range symbol will appear as a dashed arc and will be limited near the top boundary of the display area as is shown here.



If the altitude range symbol appears behind the airplane symbol as shown here, the current flight path angle is directed away from the selected altitude.



This display introduces the curved trend vector symbol which is selected or deselected by use of the TREND VECT option switch. The curved trend vector symbol indicates the path over the ground which the airplane will follow if the current turn rate and ground speed are maintained. This symbol consists of a series of three solid arc segments, each of which is preceded by a short gap. The ends of the arc segments, predict where the airplane will be in the next 30, 60, and 90 seconds based on the present ground speed and bank angle. On the 1 nautical mile per inch map scale, the curved trend vector symbol is reduced to a single arc segment representing the airplane position at 30 seconds ahead.

QUIZ

Now, let's have a short quiz of the symbols covered so far. Make certain that you have your test sheet or a piece of paper and pencil handy.

SYMBOLS QUIZ



a



b



c



d



e



f



g



h



i



j



k



l

Identify the symbols labeled a through l and the associated mode control switch where applicable.

SYMBOLS QUIZ



a



b



c



d



e



f



g



h



i



j



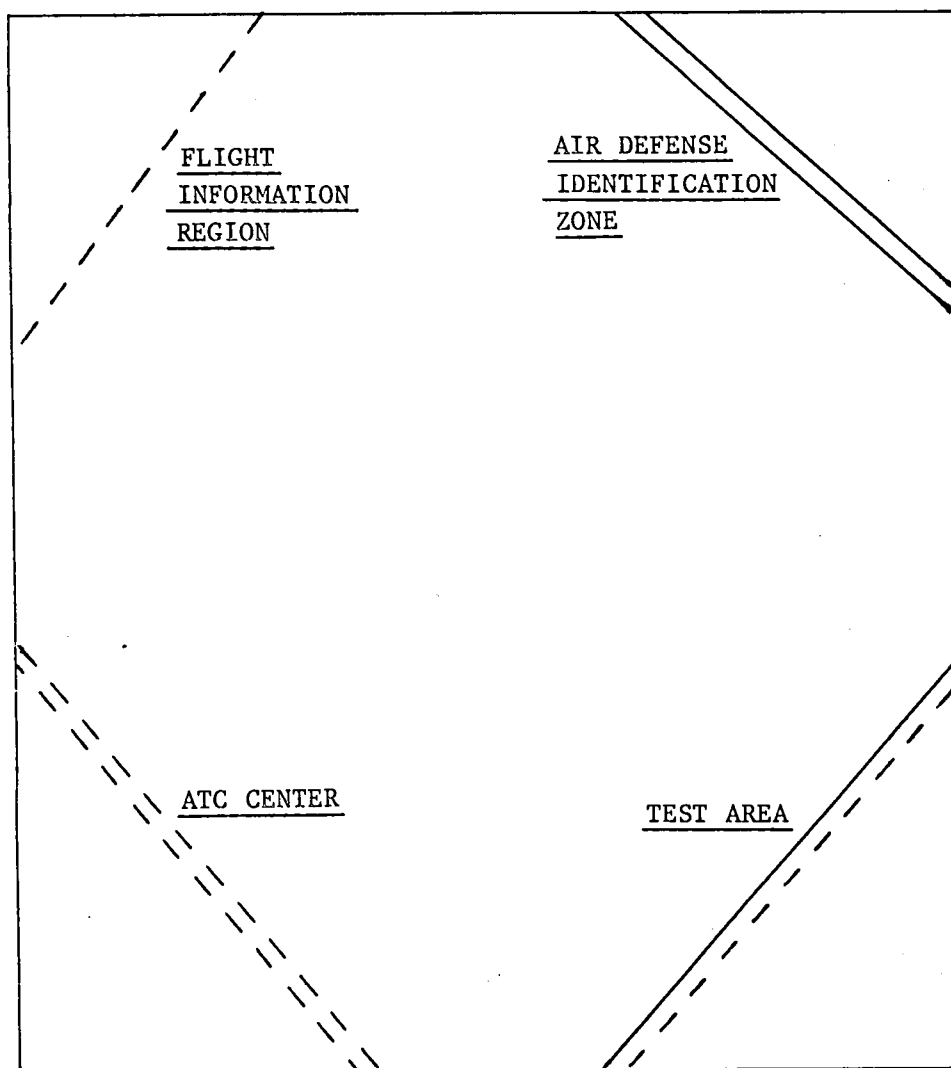
k



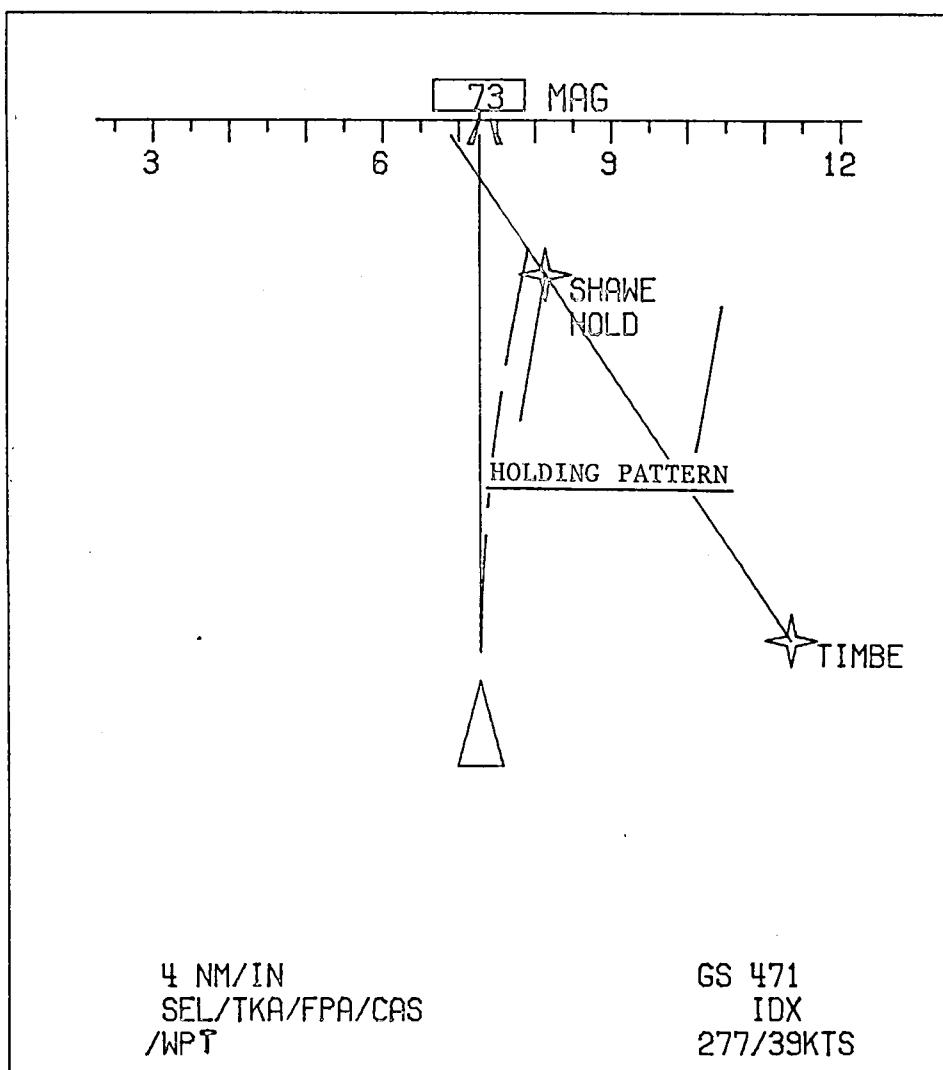
l

Here are the correct answers

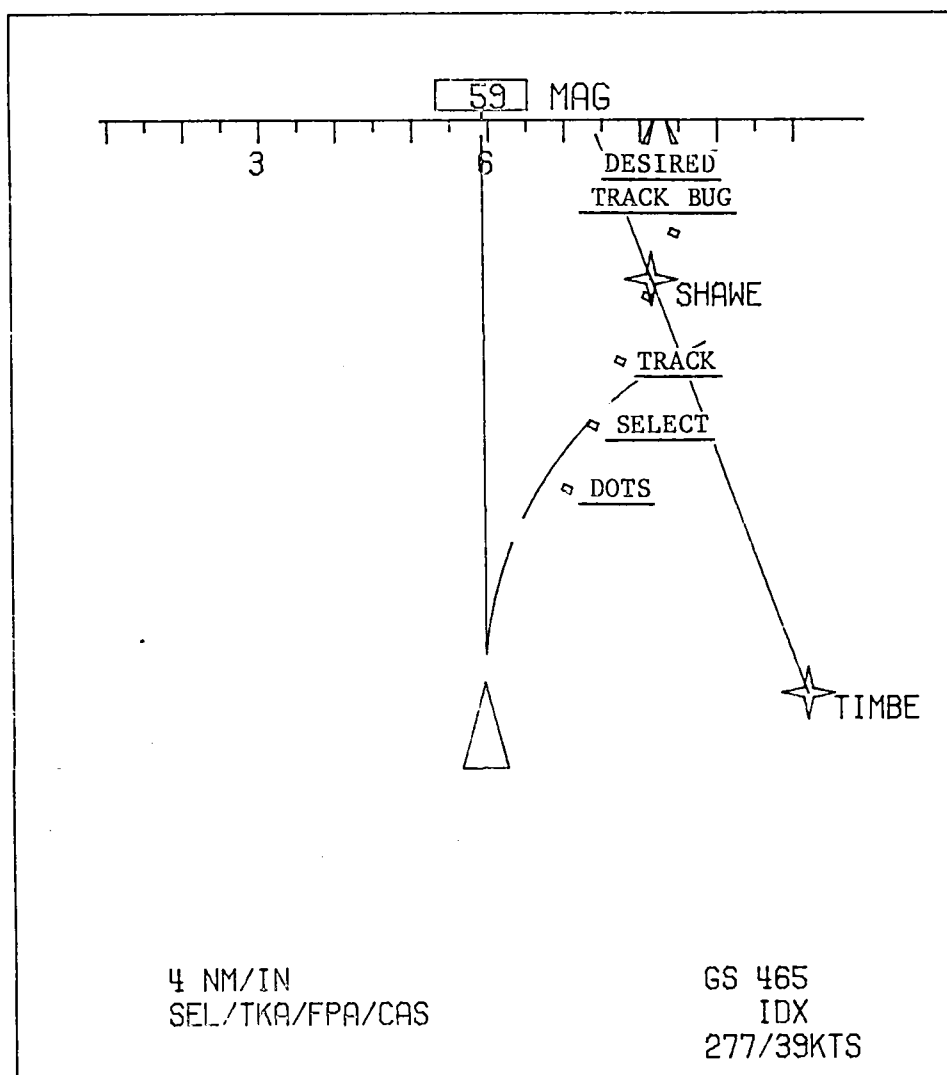
- (a) geographic reference point, GRP switch
- (b) altitude range, ALT RANGE switch
- (c) airport, AIRPORT switch
- (d) airplane
- (e) runway
- (f) VOR, NAV AID switch
- (g) VORTAC, NAV AID switch
- (h) curved trend vector, TREND VECT switch
- (i) mountain, TERRAIN switch
- (j) obstruction, TERRAIN switch
- (k) waypoint
- (l) NDB, NAV AID switch



This section deals with the remaining EHSI symbols. Presented above are the boundaries of certain geographic areas which may be significant factors in conducting flight operations. Double solid lines represent the boundaries of the air defense identification zones (ADIZ). One solid line and one dashed line represent the boundaries of a test area with the dashed line toward the enclosed area. Double dashed lines represent the boundaries of an air traffic control (ATC) center or sector. Double dashed lines are also used for warning area boundaries. Finally, a single dashed line represents the boundaries of a flight information region (FIR).



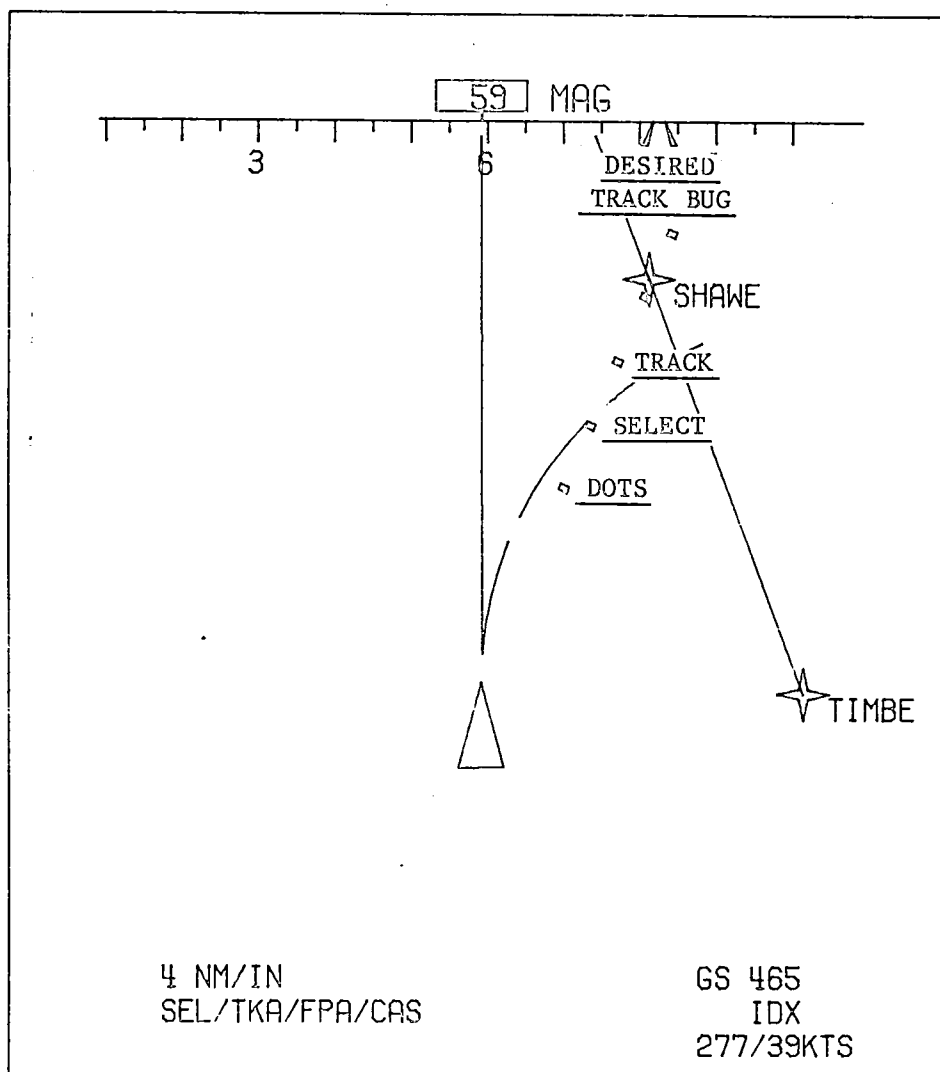
This display introduces the holding pattern symbol which is available for callup by the pilot through the navigation control and display unit. The symbol consists of two parallel lines appropriately oriented with respect to the designated holding waypoint and the word "HOLD" below the waypoint name. The length and separation of the parallel lines is dependent on the holding altitude. The lines are approximately 1 minute long below 14,000 ft and 1½ minutes long above, assuming normal B-737 holding airspeeds. A third line of annotation, WPT, also appears at the bottom left of the EHSI display when a holding pattern is called up.



This display introduces the desired track bug and track select dots symbols. The desired track bug symbol provides the pilot with a track angle reference during certain path following maneuvers. It is driven from the center of the track tape by the difference between the current track angle and desired track angle, where desired track angle is defined as:

- (1) The value in the AGCS track select window, if the track select feature is engaged or in the preselect mode, or
- (2) The planned track angle if a 2-D, 3-D, or 4-D flight plan is active.

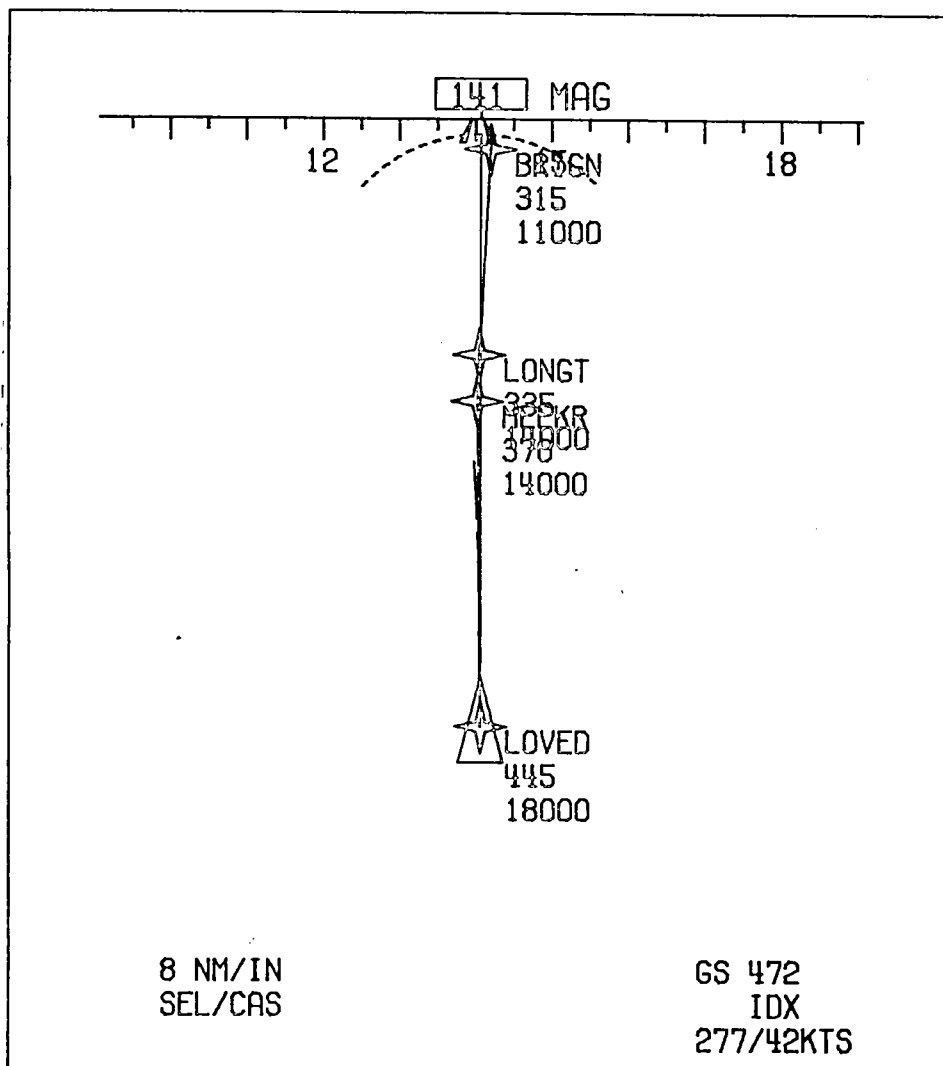
The track select dots are a series of five small dots forming a line from the apex of the airplane symbol which give the pilot a graphic picture of the path the airplane will follow if the current track angle is changed to the angle



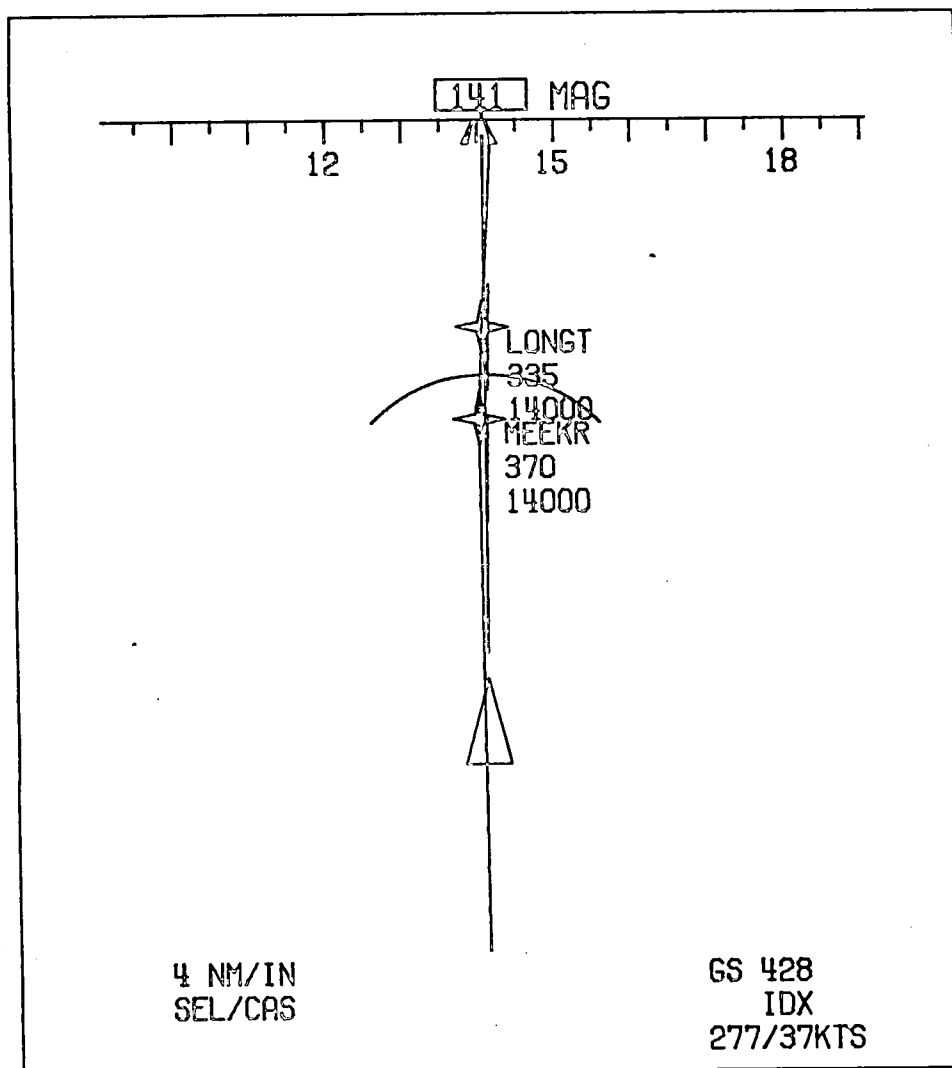
selected in the AGCS mode select panel. In positioning the track select dots, no allowance is made for the turn radius which would be required to establish a new track angle. When the airplane's track angle equals the selected angle, the dots will disappear. Finally, the track select dots are available only in the TRACK-UP mode and when the track select mode is engaged or in preselect on the AGCS mode select panel.

REPRESENTATIVE FLIGHT

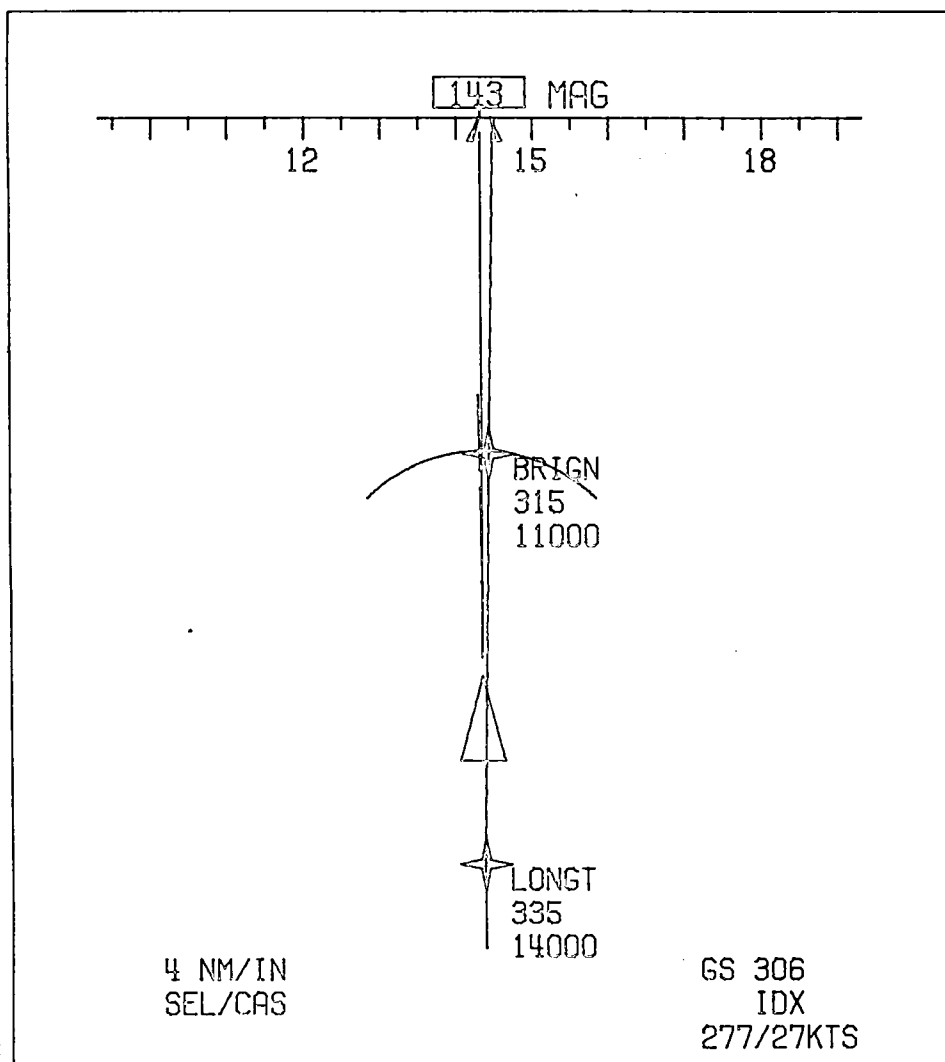
The final section of this manual presents a representative flight in the experimental Denver Stapleton International terminal area.



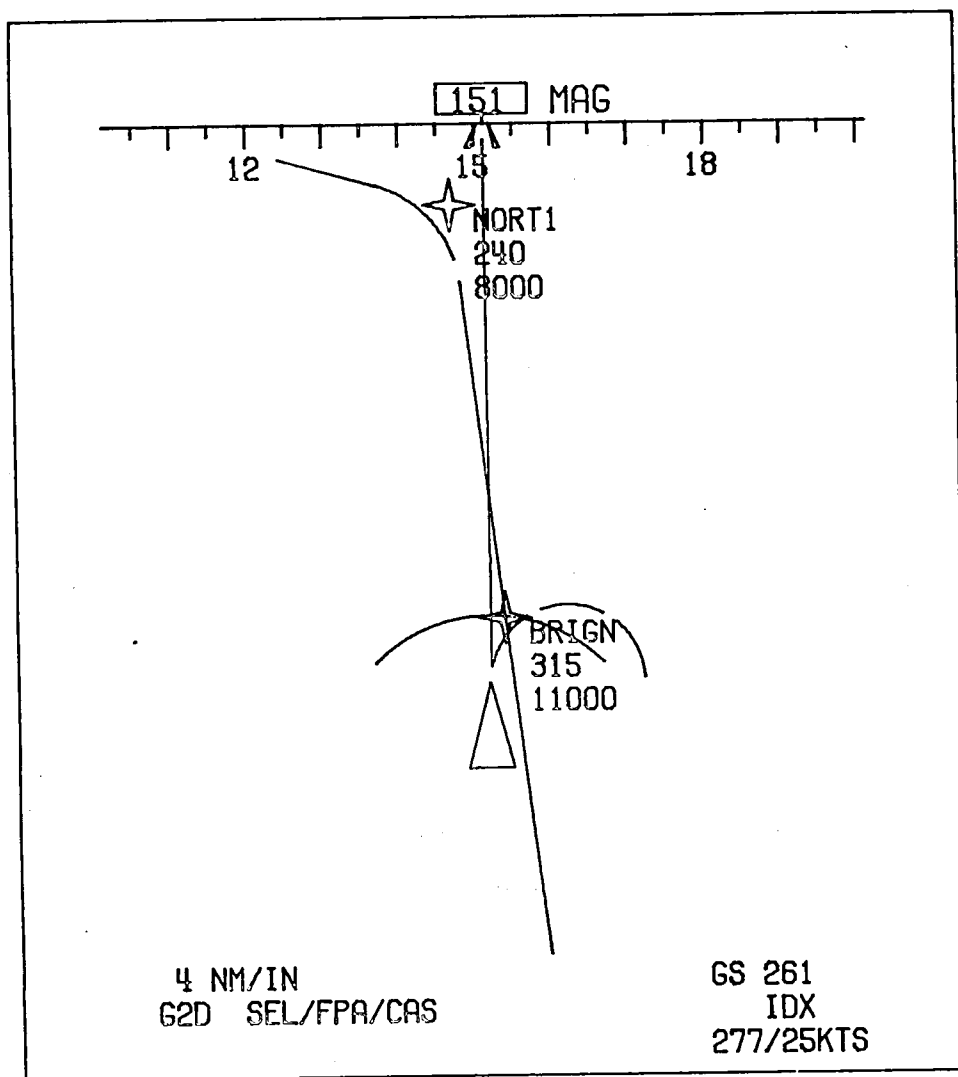
In this frame, the airplane has just crossed the LOVED waypoint with a ground speed of 472 knots. The ALT RANGE, WPT ALT, and TREND VECT option switches have been selected. Notice that the altitude/range interception point is outside the display area. The pilot has selected the TRACK-UP display mode and a map scale of 8 nautical miles per inch. Finally, the pilot has selected one of the manual control modes and the autothrottles for flying the airplane.



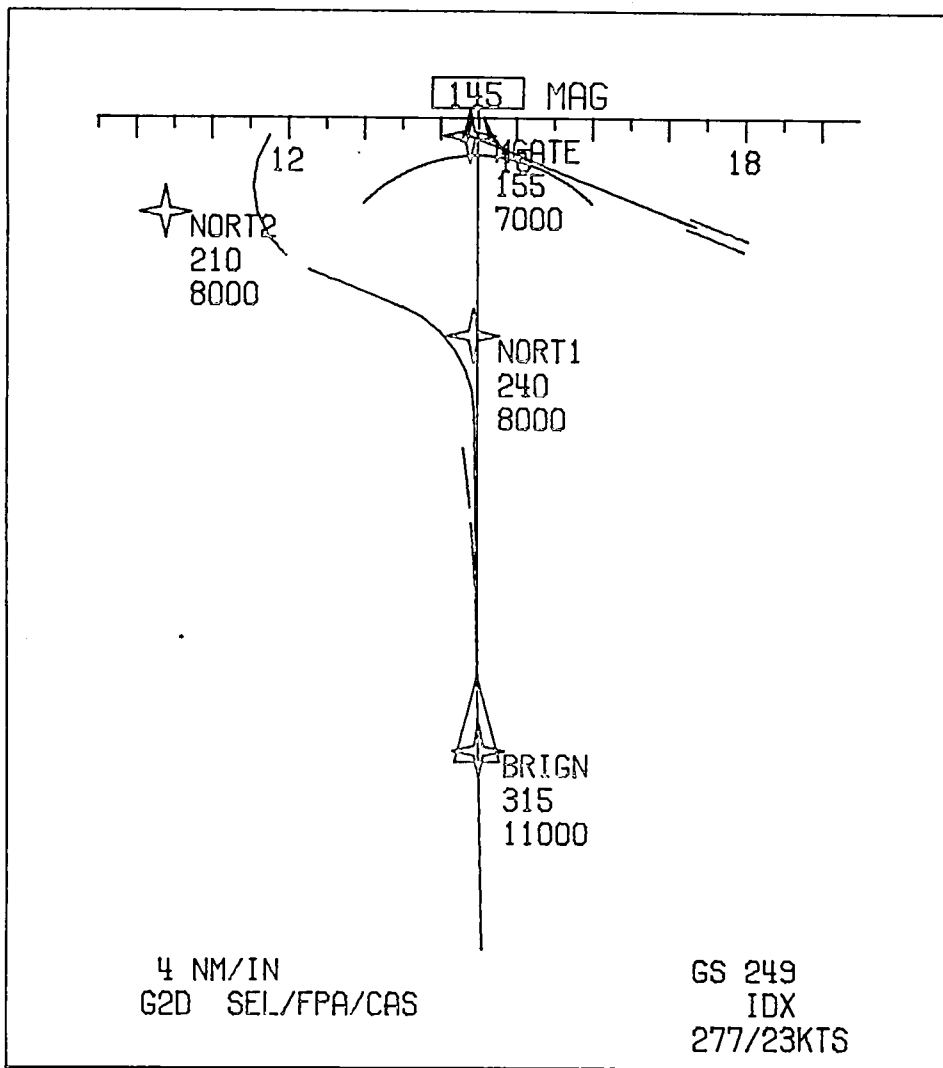
In this frame, the airplane is approaching the MEEKR waypoint at a ground speed of 428 knots. The pilot has selected a new map scale of 4 nautical miles per inch. Notice that the airplane will intercept the altitude selected on the AGCS mode select panel slightly beyond the MEEKR waypoint.



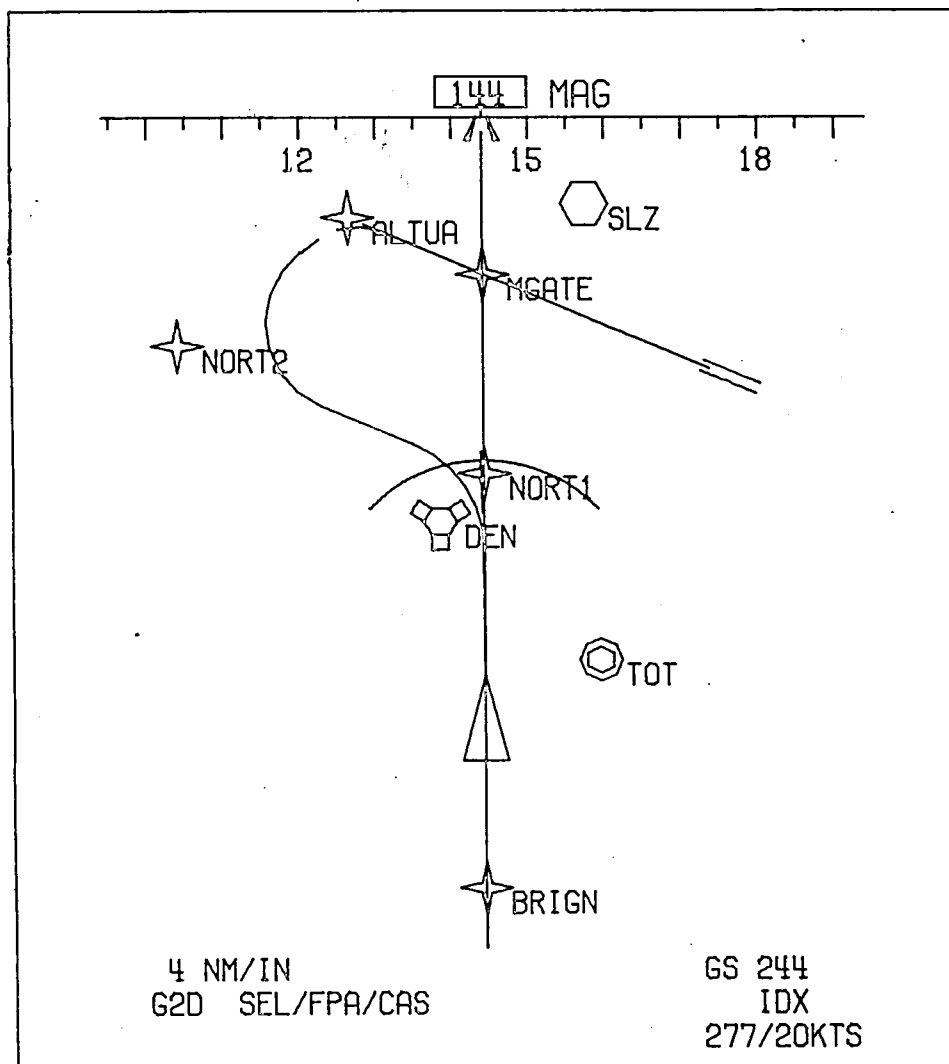
In this frame, the airplane has passed the LONGT waypoint and is descending to the BRIGN waypoint at a ground speed of 306 knots. Notice that the airplane will intercept the altitude selected on the AGCS mode select panel at the BRIGN waypoint if the present flight conditions are maintained.



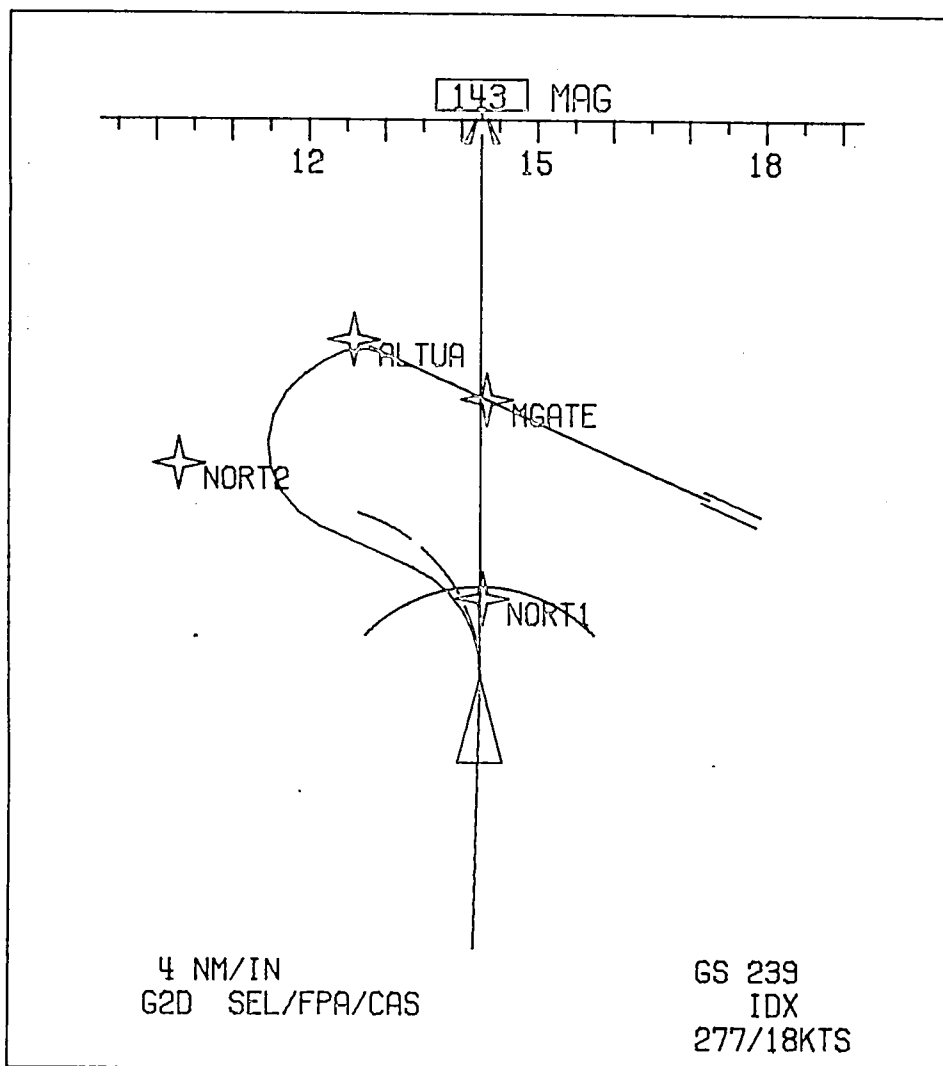
In this frame, the pilot has selected the horizontal path guidance control system (G2D). Notice that the TREND VECT option switch has been selected to display the curved trend vector which is curving to the right indicating that the airplane was slightly off course and is now having the error corrected by the horizontal path guidance control system.



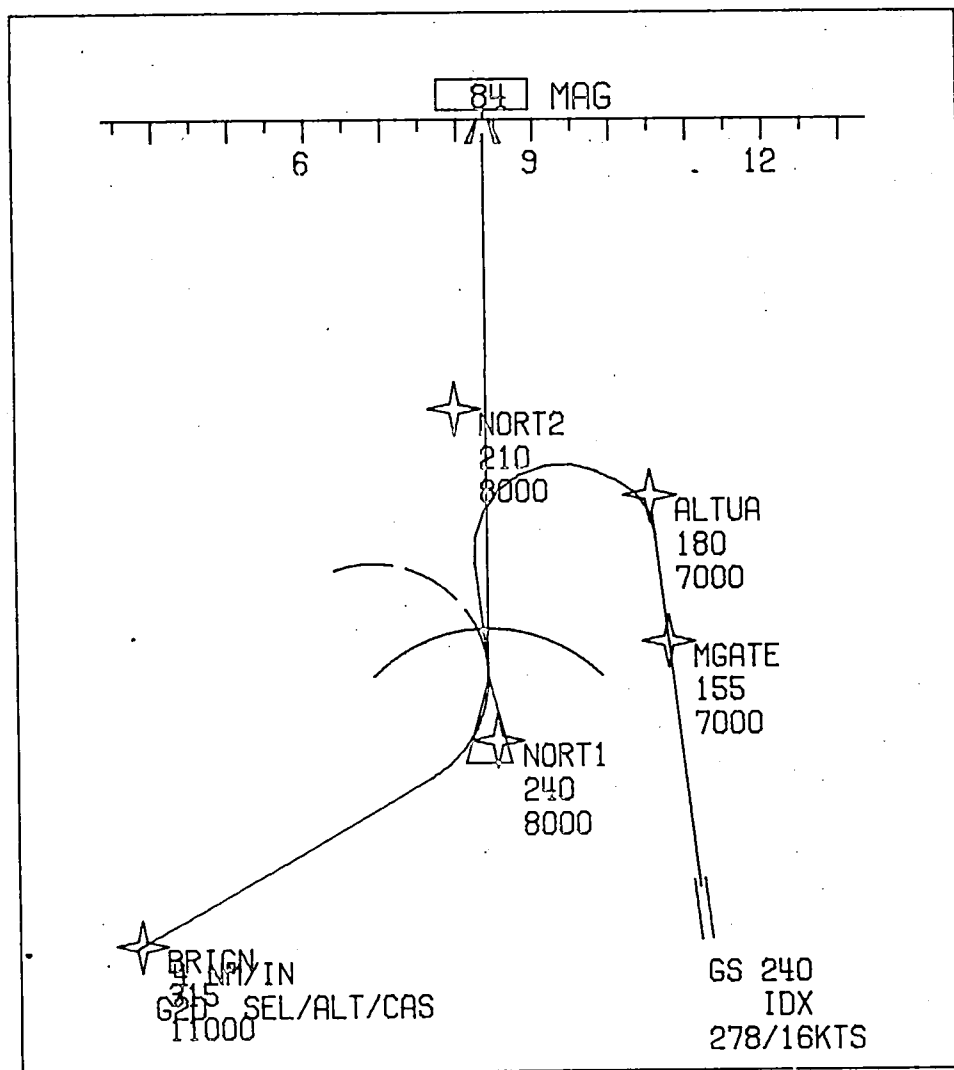
In this frame, the airplane is crossing the BRIGN waypoint at 249 knots ground speed. Notice that the destination airport runway is now inside the display area at the top of the display in the right corner. The pilot has also selected a new altitude as a reference for the altitude range symbol.



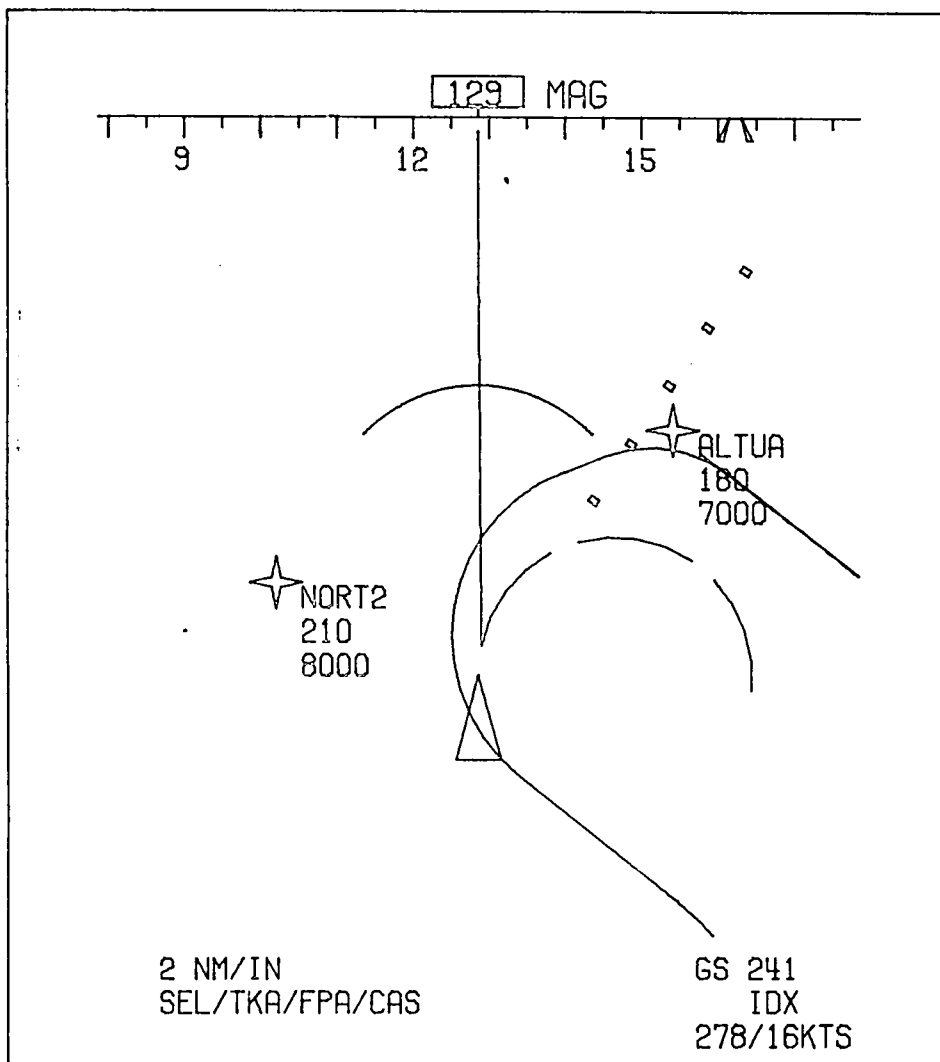
In this frame, the pilot can now see the downwind and final portions of the planned flight path. The pilot has also selected the NAV AID option switch to display the radio aids located inside the display area.



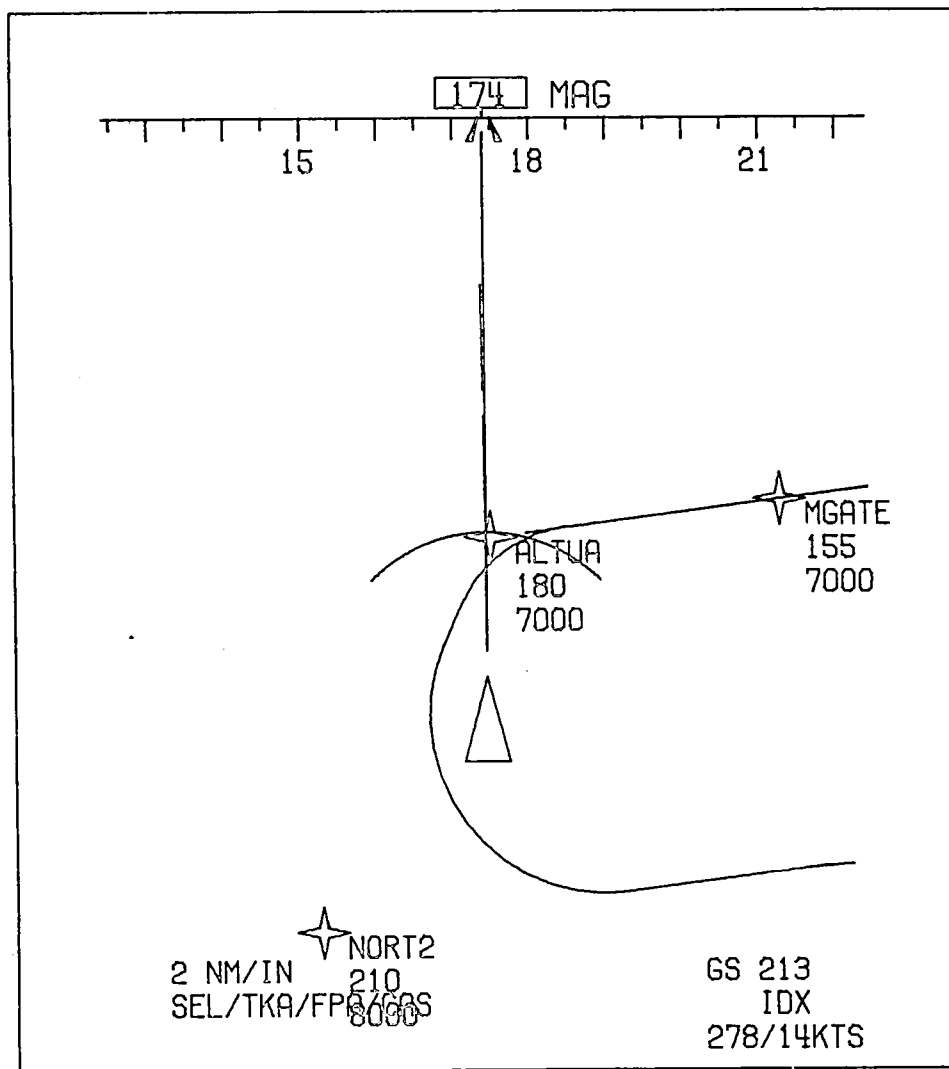
In this frame, the horizontal path guidance control system is causing the airplane to make a turn to the left. Notice the curved trend vector curving to the left.



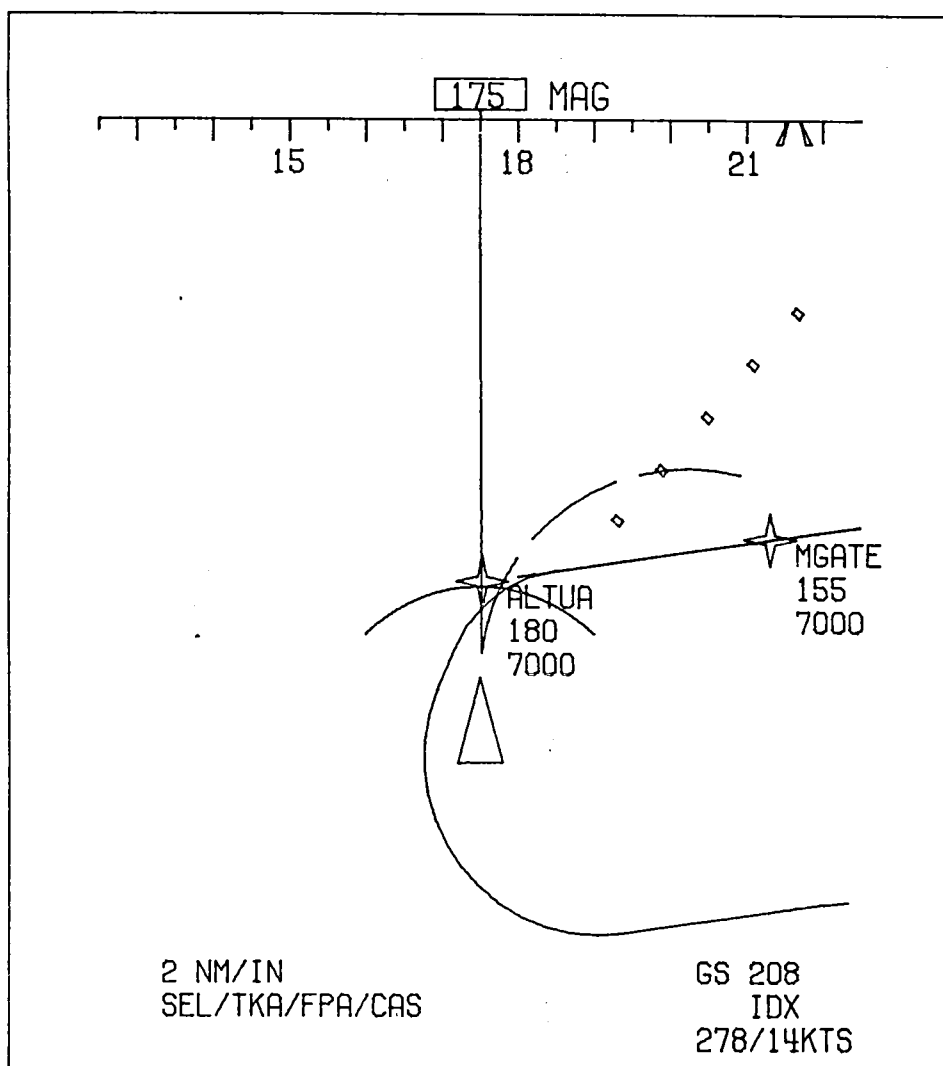
In this frame, the airplane is completing the turn to the left. Notice that the curved trend vector indicates that the airplane is still turning left. The pilot has also engaged the altitude hold function of the AGCS mode select panel signified by SEL/ALT on the display. This has been selected because the path between waypoints NORT1 and NORT2 is a constant altitude segment of 8000 feet.



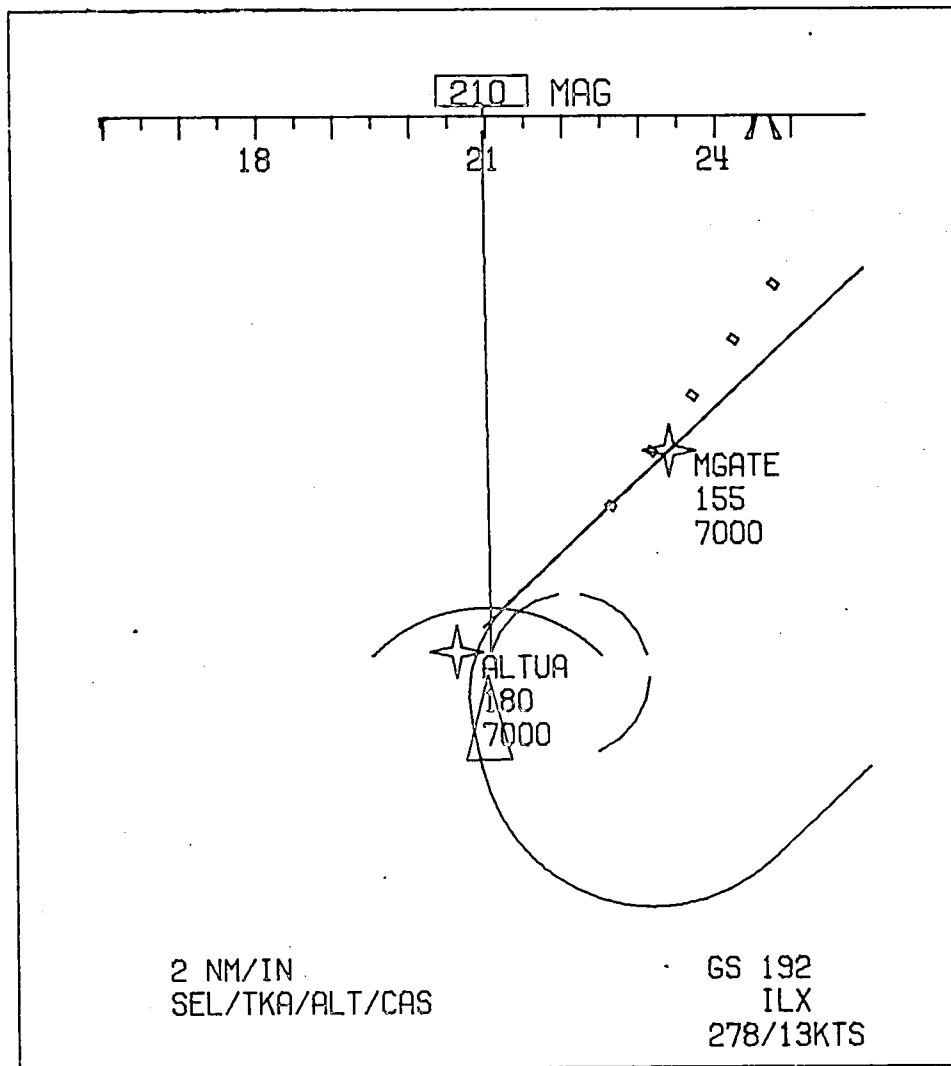
In this frame, the pilot has been commanded by the ATC controller to turn directly to waypoint ALTUA. The pilot has engaged the track select option on the AGCS mode select panel, indicated by SEL/TKA on the display, and is proceeding to overlay the track select dots on the ALTUA waypoint. The pilot has deselected the altitude hold function and has selected a new reference altitude for the altitude range symbol. Finally, a new map scale of 2 nautical miles per inch has been selected.



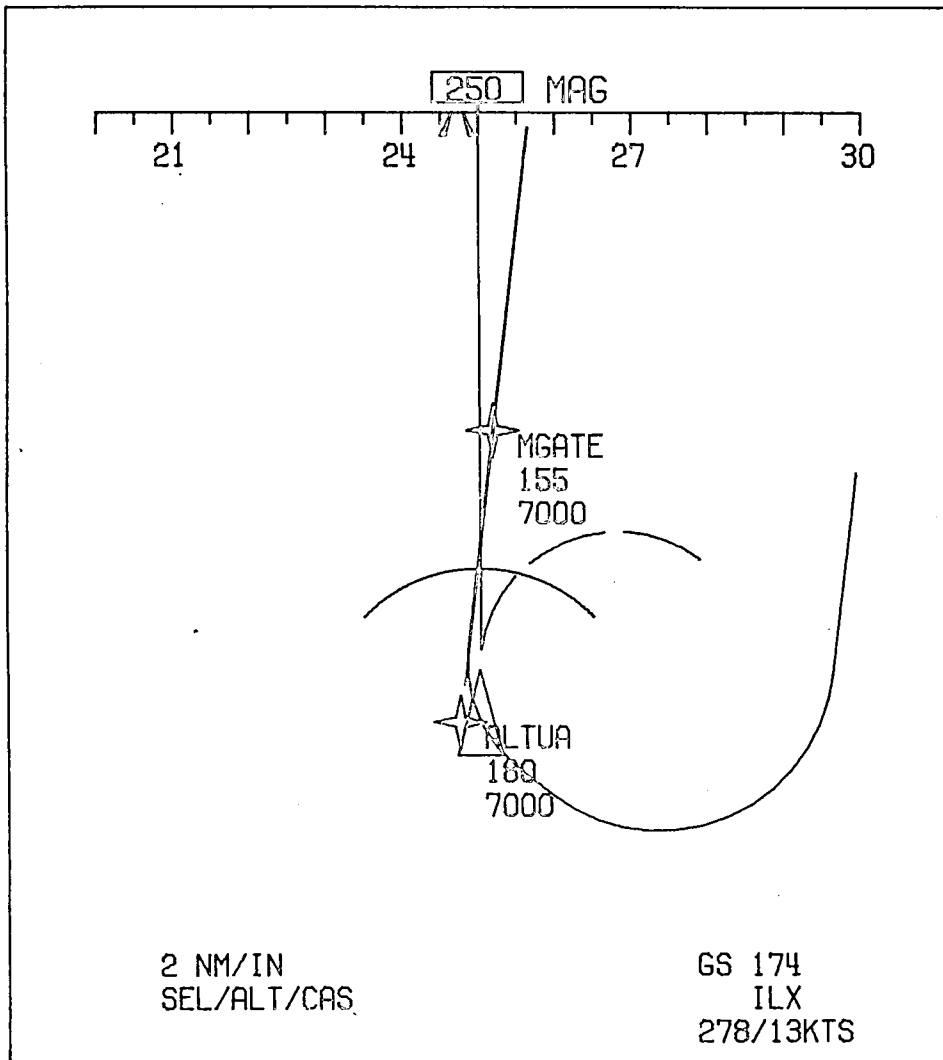
In this frame, the airplane has completed its turn and is flying toward ALTUA. The airplane will reach the desired altitude at this waypoint. Notice that the track select dots have disappeared. This is due to the present track angle equalling the selected track angle.



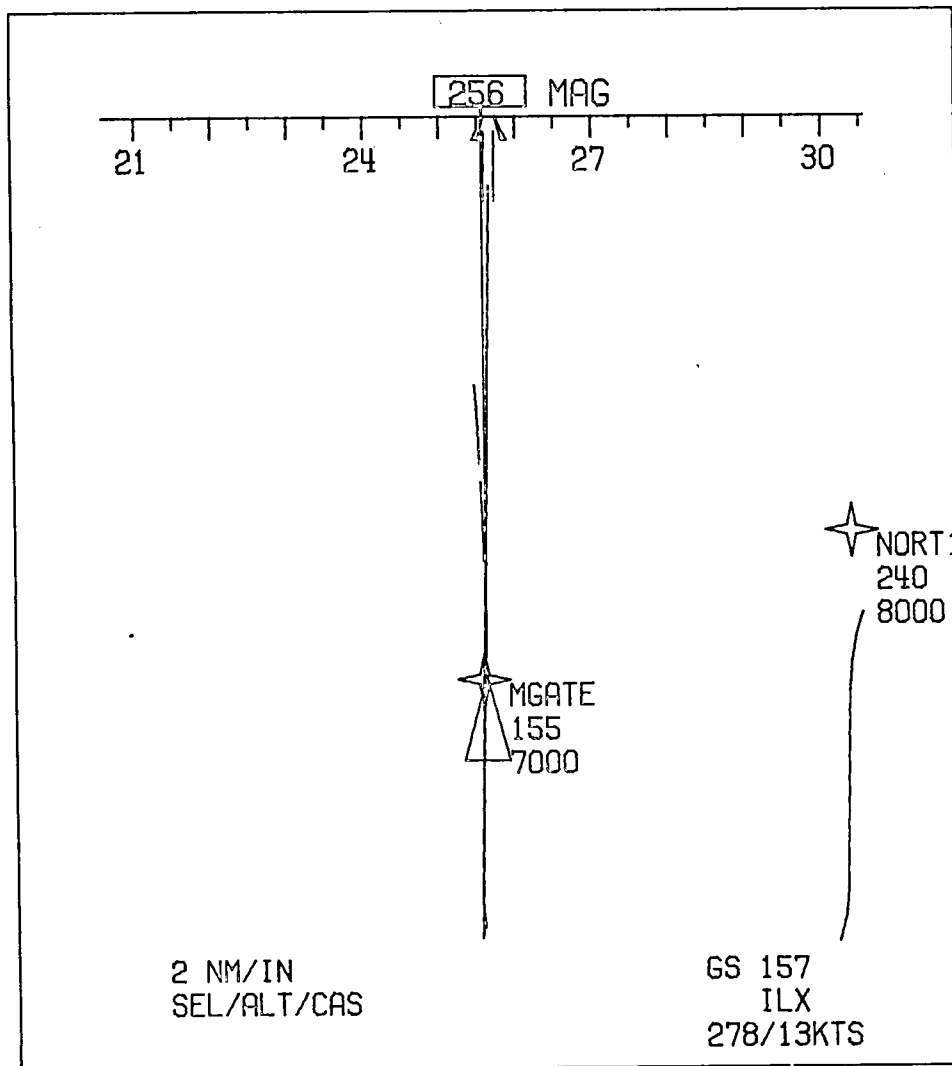
In this frame, the ATC controller has commanded a turn to waypoint MGATE. The pilot is starting the turn and will overlay the track select dots on the MGATE waypoint.



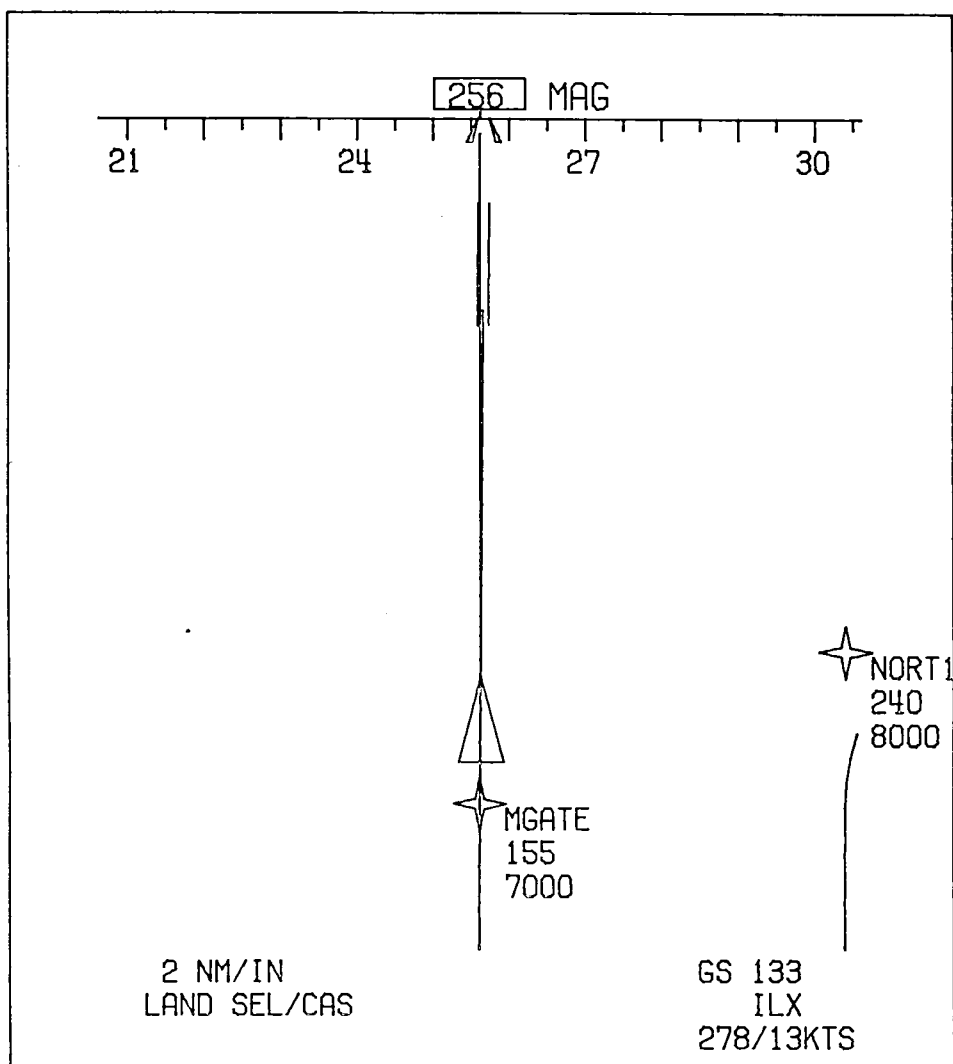
Here the pilot has completed overlaying the track select dots on the MGATE waypoint, and has also selected the altitude hold function to maintain the airplane's current altitude. Notice that the airplane is now using ILS information, denoted by ILX on the display, to estimate its position.



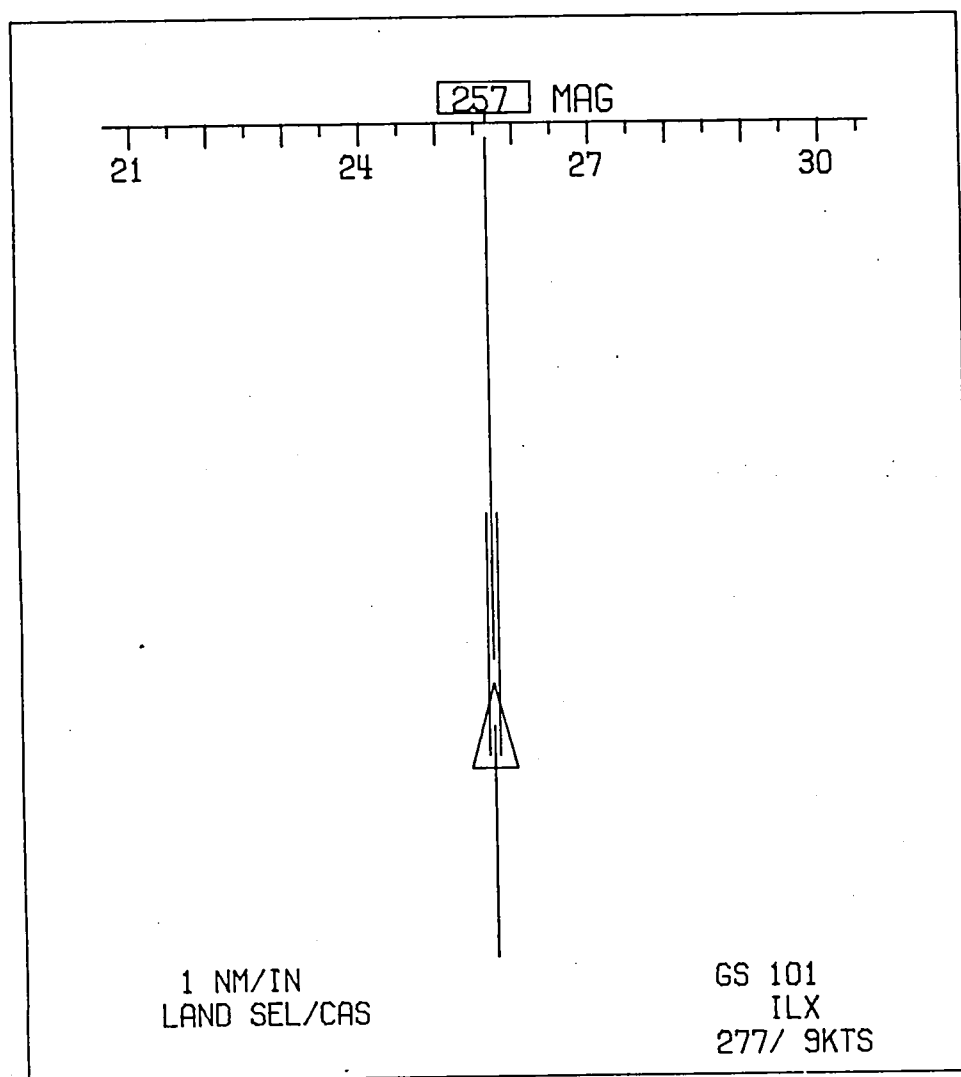
In this frame, the pilot has armed the autoland system, and the airplane is turning to intercept the localizer and glideslope.



Here the airplane is completing its turn to intercept the localizer and glideslope.



In this frame, the autoland system has engaged as denoted by the word LAND in the lower left corner of the display. The word LAND appears only when both localizer and glideslope have been captured.



Finally, in this frame, the airplane is shown on the runway with a ground speed of 101 knots, and the display is set at the 1 nautical mile per inch scale.

UNDERSTANDING THE EHSI IS ESSENTIAL

If you had trouble with either of the quizzes, or trouble understanding the flight example, you should review the appropriate sections of this manual. Absolute knowledge of the symbols and their function is essential before you move to the next lesson in this series. One other tip - even if you correctly answered all of the quizzes, it wouldn't be a bad idea for you to review this lesson at a later date. It has the same value as re-current training.

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2. Gandelman, Jules; and Holden, Robert: A Pilot Training Manual for the Terminal Configured Vehicle Electronic Attitude Director Indicator. NASA CR-159195, January 1980.

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16. Abstract <p>This manual presents the initial phase of a training course for the Terminal Configured Vehicle Electronic Horizontal Situation Indicator (EHSI). This manual provides the basic instructional format for the introduction to the EHSI and the strategy for learning the EHSI symbology and their interpretation. The strategy is to start with the basic symbols which are present at all times, to present the optional symbols, and then to add appropriate symbols as desired during the various portion of a flight. Each page of this manual is divided into two parts. The upper half of the page is a reproduction of the EHSI display or various other instructional material, such as title pages, quizzes, answer pages, etc. The bottom half of the page contains text associated with the upper half. This allows for easy production of an audio-visual package when required for use with large groups of students.</p>					
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